Water Resource Inventory Area (WRIA) 7 Routine Streams Water Quality Monitoring: Summary of Conditions 2011 – 2013

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Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section
King Street Center, KSC-NR-0600
201 South Jackson Street, Suite 600
Seattle, WA 98104
206-477-4800 TTY Relay: 711
www.kingcounty.gov/EnvironmentalScience

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Submitted by:

Raymond Timm, Ph.D.
King County Water and Land Resources Division
Department of Natural Resources and Parks

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Executive Summary

Beginning in 2011, funds from King County's Surface Water Management (SWM) fees have been used to conduct routine water quality monitoring in portions of the County that are included in the Snohomish River drainage, or Water Resources Inventory Area 7 (WRIA 7). Objectives of this program are focused on quantifying long-term water quality trends that might help inform the management of stormwater, salmon recovery efforts, land use regulation, and an increasingly variable climate. This effort expands on the existing ongoing King County Routine Streams Monitoring Program that has historically been centered in WRIAs 8 (Greater Lake Washington) and 9 (Green River/Vashon). The WRIA 7 Routine Streams Monitoring program consists of twelve sampling sites that are distributed throughout the watershed on tributary streams and mainstem rivers that drain a variety of land covers. This report presents results from the first three years of this ongoing monitoring effort in WRIA 7.

For the WRIA 7 monitoring effort, eleven permanent sampling locations were established in the Snoqualmie River drainage, and one in the Skykomish River. Data are organized by the water year calendar (October 1 – September 30), consist of grab samples, and are collected once per month. Parameters measured are commonly referred to as "Conventional Water Quality Parameters" and include *dissolved oxygen (DO)*, *temperature (T)*, *pH*, *specific conductance*, *various nutrient measures*, and *fecal coliform bacteria (FC)*. These measures are integrated into a single water quality index score (WQI) developed by the State of Washington. The WQI provides a convenient framework for comparing annual water quality conditions among different locations within the WRIA, across the County, and throughout the Puget Lowland Ecoregion.

The first three years of monitoring data collected through this program (2011-2013) suggest that water quality conditions in WRIA 7 are currently mostly of low concern, although a few subbasins are of moderate concern. Parameters that appear to be responsible for water quality concerns include temperature, fecal coliform bacteria, dissolved oxygen, and nutrients. Specifically, 6 of the 12 sampling locations drain systems that consistently exhibit good water quality and are considered to be of "low concern" according to WQI criteria. These stations include Cherry Creek, Griffin Creek, Harris Creek, the Snoqualmie River at Duvall, the Tolt River, and the Skykomish River. Four of the sites have WQI scores that straddle the threshold between "low concern" and "moderate concern." These locations are the Middle Fork Snoqualmie River, North Fork Snoqualmie River, the Raging River, and the South Fork Snoqualmie River. Finally, two of the sites drain watersheds that so far, have exhibited consistent water quality problems and are considered to be of "moderate concern" according to their WQI scores. These include Ames Creek and Patterson Creek, which both have repeated high temperatures, low DO, and high bacteria concentrations.

When rolled into the WQI, the results of routine monthly water quality monitoring can illuminate seasonal patterns among individual parameters and provide insight as to how

parameters vary within respective watersheds. The WQI integrates all measured water quality parameters from a given year, into a ratioed index that is useful for comparing water quality across watersheds and for understanding long-term trends. In the short term, there are some obvious spatial patterns emerging. For example, the sampling locations exhibiting the lowest WQI scores all fall within the floodplain-dominated landscapes of the Snoqualmie River and are likely owing to the intensity of human land uses in the floodplain. Conversely, those sampling locations with the most consistently high WQI scores generally drain watersheds that are dominated by forest. Of course there are exceptions to these observations. Notably, the Snoqualmie River at Duvall exhibits high WQI scores and lies squarely in the mainstem floodplain and immediately downstream of a municipal wastewater treatment facility. In addition, the Raging River, the North Fork Snoqualmie, and the Middle Fork Snoqualmie sites, while located within the mainstem floodplain of the Snoqualmie River, drain mostly forested landscapes, and have lower than might be expected WQI scores.

Across all sampling locations, dissolved oxygen rarely fell below Washington State water quality criteria. A notable exception was Ames Creek which exhibited consistently low DO relative to other streams in this monitoring program. Highest reported temperatures in the watershed occurred at the mouth of the Raging River, in the Middle Fork Snoqualmie River, and the Snoqualmie River at Duvall. Values of pH reported in this monitoring program ranged between 6.3 and 9.4. Most recorded measures of pH hovered around neutral (pH=7) with highest levels reported during the warmest months (July, August, and September) at the mouth of the Raging River. Turbidity and TSS were consistently high in Ames creek and in the Snoqualmie River at Duvall. Elevated values in these parameters may be an indication that excessive sediment and nutrient laden runoff are draining from agriculturally dominated watersheds. In addition, Ames, Patterson, and Harris Creeks all had relatively high levels of total nutrients, particularly total nitrogen. Again, these findings are consistent with the agricultural land uses that dominate their drainages. The final parameter is fecal coliform (FC) bacteria. There are multiple ways to quantify FC concentrations under state water quality guidelines that are presented in this report. However, irrespective of analytical approach, FC values were consistently highest at the end of the dry summer months and indicate that fecal coliform pollution may be problematic in many watersheds of WRIA 7. Owing to the general ubiquity of FC problems in surface waters throughout King County, it should probably be watched in all of the study area.

Barring unforeseen changes in funding availability, these 12 sites in WRIA 7 will continue to be monitored over time as part of King County's Routine Streams Monitoring Program. The information gathered on water quality in WRIA 7 streams fills an identified data gap in understanding water quality conditions in this part of King County. However, the value of the information will increase as time passes, as a longer data set will allow for an analysis of water quality trends, and comparisons with other watersheds in King County. As our knowledge improves, this dataset will inform many of the natural resources management challenges facing the County including an increasingly variable climate, imperiled species recovery, water resources management, and land use planning.

The WQI and supporting data for the routine streams monitoring program is available through the following website:
http://green.kingcounty.gov/wlr/waterres/streamsdata/WQISummary.aspx

Acknowledgements

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1.0 INTRODUCTION

King County's Watershed Resource Inventory Area 7 (WRIA 7) Routine Streams Monitoring program was established during 2011 and consists of twelve sampling sites that are distributed throughout the King County portion of the watershed on tributary streams and mainstem rivers. A variety of land covers that typify the WRIA drain to these sampling locations. Historically in King County, routine streams monitoring has been centered on WRIAs 8 and 9. However, in 2011, owing to an increase in surface water management (SWM) funding, sampling expanded to include the King County portions of the WRIA 7 drainage (Figure 1). Prior to the beginning of this effort there was no systematic water quality monitoring in the watershed. With the exception of the long-term water quality monitoring station established by the Washington State Department of Ecology (DOE, site # 07D130), and the total maximum daily load (TMDL) studies that were triggered by excessive temperature, ammonia-nitrogen, 5-day biological demand (BOD-5), and fecal coliform bacteria, much of the water quality data collected in the King County portions of this watershed are from relatively short term, project-based efforts, or have no consistent locations (Kaje, 2009). The TMDLs[1] for Ammonia-N, BOD-5, and Fecal Coliform were completed in 2008 (Sargeant and Svrjcek, 2008). The temperature TMDL[2] was completed during 2011 (Svrjcek et al., 2011). In a broader sense, this Routine Streams Monitoring effort expands King County's long-term water quality dataset to provide information for previously underserved rural areas of the County.

Many water quality measures are related to each other, and some are driven by others. For example, water chemistry parameters like dissolved oxygen (DO), and pH are related to temperature. In addition, temperature can also affect the solubility and cycling of nutrients (Wetzel, 1983). Nutrient loadings, along with total suspended sediments (TSS), and fecal coliform bacteria (FC) concentrations can be important indicators of land use problems and can vary strongly by season (Johnson et al., 1997). As the universal solvent, water integrates the landscapes through which it flows and picks up unique collections of dissolved and suspended materials that can help describe watershed conditions.

The WRIA 7 consists of two major drainages on the west side of the Cascade Mountains. The Snoqualmie River lies almost completely within King County and drains nearly 667 square miles. It joins the Skykomish River, near the city of Monroe to form the Snohomish River, ultimately emptying into Puget Sound near the city of Everett, Washington. The portion of the Skykomish River that lies within King County, drains 20 percent of the 830 square miles Skykomish total drainage area. When combined, the Snoqualmie and Skykomish rivers drain nearly 40 percent of King County. These areas are the focus of this monitoring program.

[1] https://fortress.wa.gov/ecy/publications/SummaryPages/0803005.html
[2] https://fortress.wa.gov/ecy/publications/SummaryPages/1110041.html

The Snoqualmie River occupies two distinct geomorphic provinces. Above the 270 feet high falls near the city of Snoqualmie, the river drains steep forested mountains and is alluvial in the valley bottoms. Below the falls, the river meanders for more than 40 miles through a post-glacial valley that is dominated by agricultural land uses. At its confluence with the Skykomish River near Monroe, Washington, the two rivers form the Snohomish River (Pess et al., 2003; Kaje, 2009).

The south fork of the Skykomish River drainage covers the northeast third of King County's portion of the WRIA. The portion of the Skykomish River that lies within King County is similar geomorphically to the upper Snoqualmie. It has four main tributaries that drain steep forested mountains. The Beckler and Tye rivers originate in the mountains of Snohomish County while the Foss and Miller rivers originate in the Alpine Lakes Wilderness area of King County.

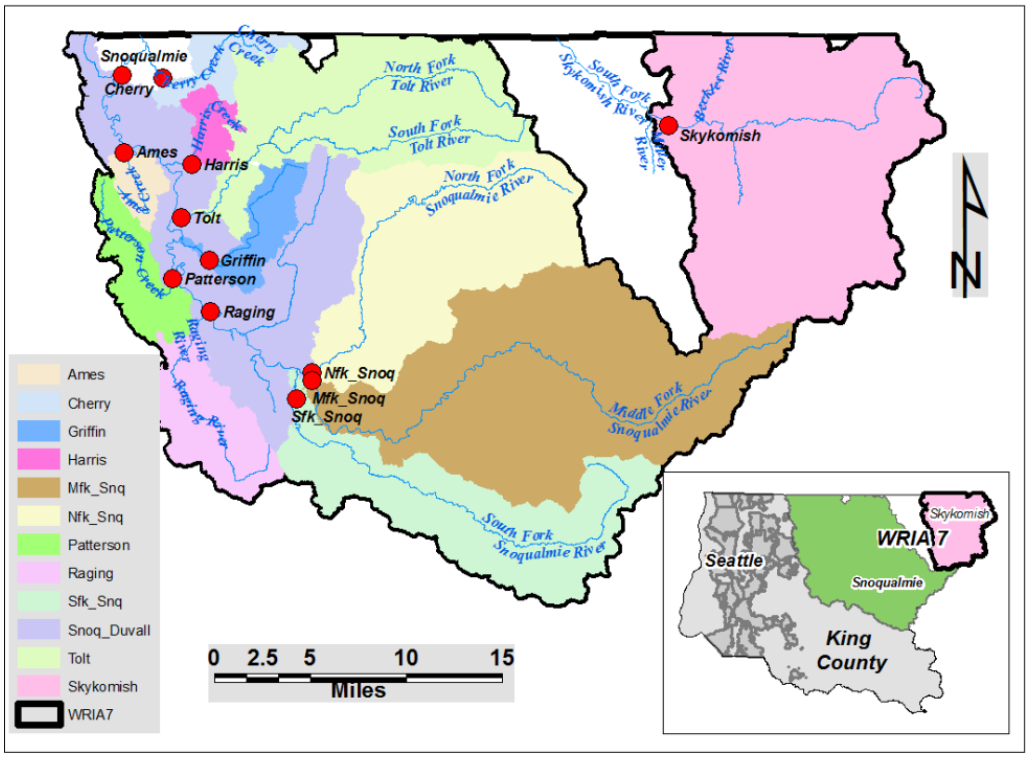

Figure 1. Twelve routine stream monitoring locations added to King County's portion of WRIA 7 and upstream drainage areas.

2.0 METHODS

2.1 Sample Collection and Laboratory Analysis

Monthly water quality measurements were taken from grab samples using both laboratory and field methods (Table 1). Sampling began in February, 2011 and is ongoing. Field methods employed a calibrated probe that was placed in the water at each respective sampling location, and used to measure dissolved oxygen (DO), hydrogen ion concentration (pH), temperature (T), and specific conductance. In addition, water samples were collected in clean high density polyethylene (HDPE) sample bottles, stored on ice in the dark, and transported to the King County Environmental Laboratory (KCEL) for analysis. Laboratory methods were used to quantify fecal coliform bacteria concentrations, total suspended solids (TSS), total Nitrogen, Ammonia Nitrogen, Nitrate+Nitrite Nitrogen, and Orthophosphate Phosphorus.

Table 1. Water quality parameters measured, units of measurement, method followed, and precision of measurement.

Parameter	Units	Method*	MDL	RDL
Fecal Coliforms	Colony forming units ×100mL^{-1}	Lab/culture	1	1
Dissolved Oxygen	Mg×L^{-1}	Field probe	0.1	0.5
pH	-log H+ ion concentration	Field probe	N/A	N/A
Total Suspended Solids	Mg×L^{-1}	Lab (SM 2540-D)	0.5	1
Temperature	Degrees C	Field probe	N/A	N/A
Total Nitrogen	Mg×L^{-1}	Lab (SM 4500-P-B-F)	0.005	0.01
Specific Conductance	Mhos×cm^{-1}	Field probe	1	5
Ammonia Nitrogen	Mg×L^{-1}	Lab (SM 4500-NH3-G)	0.01	0.02
Nitrate+Nitrite Nitrogen	Mg×L^{-1}	Lab (SM 4500 NO3-F)	0.01	0.04
Orthophosphate Phosphorus	Mg×L^{-1}	Lab (SM 4500-P-F)	0.0005	0.002

*Specific laboratory methods can be downloaded from the King County Environmental Laboratory at: http://www.kingcounty.gov/environment/data-and-trends/environmental-lab.aspx

2.2 Subbasin Descriptions

King County's WRIA 7 routine streams monitoring program includes twelve subbasins within the Snoqualmie and Snohomish River basins. Each sampling location was chosen in order to isolate important tributaries and mainstem river sections that are thought to be

major contributors to overall water quality in the basin. In consultation with WRIA 7 staff, members of the Science Section of King County Water and Land Resources Division (WLRD) identified the 12 sampling locations that are the basis for this program. Upslope of respective sampling sites, watershed drainage area was estimated in each subbasin. Each subbasin was characterized in terms of major land covers as a proportion of contributing drainage area (Table 2; Figure 1). Land cover categories were summarized as *forest*, which included coniferous, deciduous, mixed forest, recently logged, and recently regenerated forest. *Urban* land covers included high density and mixed low density urban. The *Other* category captured various intensities of presumed agricultural uses (i.e., bare, herbaceous vegetation, scrub/shrub) as well as open water. Each of these dominant land covers brings a unique suite of watershed impacts that are often manifest differently in terms of physical, chemical, and biological responses in surface waters (Alberti et al., 2007). The watersheds draining to our sampling locations exhibit the range of land covers and land uses typical of the WRIA in general (Kaje, 2009). Percent forest land cover ranges from 53 percent (Ames Creek) to more than 90 percent (Griffin Creek); urban land covers range from 0 percent (Griffin Creek) to 10 percent (Patterson Creek); and other land covers including those associated with agricultural land uses comprise from 9 percent (Griffin Creek) to as much as 40 percent (Ames Creek) of watershed area (Table 2).

Table 2. Subbasin descriptions by contributing drainage area, major land use categories, and discharge characteristics.

Basin	Subbasin	Area (Ac)	Forest (%)	Urban (%)	Other (%)	Mean Annual Flow (cfs)
Snoqualmie	Ames	5171	53	6	41	56
	Cherry	8531	86	2	12	44
	Griffin	10126	91	1	8	42
	Harris	5301	76	6	18	16
	Middle Fork Snoqualmie	108941	67	1	32	1239
	North Fork Snoqualmie	66208	78	1	21	506
	Patterson	12909	58	10	32	21
	South Fork Snoqualmie	52137	70	6	24	298
	Raging	20447	83	3	14	132
	Snoqualmie at Duvall	67587	65	8	27	3721
	Tolt	61485	83	1	16	575
Skykomish	Skykomish at Skykomish	108610	71	1	28	3976

Each subbasin varies by drainage area as well as by the mix of land uses present. Study subbasin areas range from approximately 5,000 acres to more than 110,000 acres. Mean annual discharges vary with drainage area and range from 16 cubic feet per second (cfs) at the King County Harris Creek stream gauge (22A) to nearly 4,000 cfs at the Skykomish gauge (USGS gauge 12134500). As a result, there are unique combinations of human activities and natural conditions that can affect water quality. Owing to the continuous changes in watershed character from headwaters areas down to their respective mouths, water quality conditions can vary longitudinally (Vannote et al., 1980). Water quality measurement locations are placed at or near tributary junctions that segregate specific types and intensities of land covers including industrial forestry lands, agriculturally dominated landscapes, and suburbanized areas.

Many of the fish stocks in the Snohomish River drainage have unique habitat requirements and geographic distributions, and are depressed relative to historic conditions. For example, both Chinook salmon and steelhead trout are listed as "threatened" under the endangered species act (ESA). It is estimated that Chinook in the basin are at about only 3.5 percent of their historic abundance (Snohomish County, 2005). Steelhead in the Snohomish system are represented by both summer run and winter run fish. Stocks of summer run steelhead are generally healthier than winter run fish. The local stock of steelhead that is most closely associated with a long-term water quality sampling location in this program is the South Fork Skykomish Summer Steelhead population. This stock of fish is one that is considered to be "healthy" by the Washington Department of Fish and Wildlife (WDFW, 2014). In addition, there are four ESA - listed bull trout populations – North Fork Skykomish, Troublesome Creek, Salmon Creek, and South Fork Skykomish – each have populations estimated at less than 100 individuals. By contrast, the Snohomish River basin produces between 25-50 percent of all coho salmon in Puget Sound (Snohomish County, 2005). In addition, odd year pink and fall chum salmon use the system extensively (WDFW 2014).

2.2.1 Ames Creek

The Ames Creek sampling location drains nearly 5,200 acres and has the highest proportion of non-forest land uses in the WRIA 7 study area. Even so, forested area comprises 53 percent of the watershed (Table 2). The routine sampling location is approximately 900 feet above the confluence with the Snoqualmie River (Figure 1). The riparian corridor has been heavily altered in floodplain areas in particular, but upland areas also feature substantial encroachment of residential and agricultural development into riparian areas. In addition, the watershed exhibits a loss of wetlands and mature forest cover (Kaje, 2009). These types of changes can contribute to water quality degradation, affecting stream temperature and the input of pollutants and sediment. The loss of wetlands and forest cover can exacerbate winter flood flows and decrease summer low flows owing to decreased interception and infiltration of precipitation (DeGasperi et al., 2009). Despite substantial changes in watershed land uses, Ames Creek has known distributions of fall Chinook, coho, and fall chum salmon. Winter steelhead, pink salmon, and bull trout are thought to use parts of the stream as well (WDFW, 2014).

2.2.2 Cherry Creek

Cherry Creek is an east-to-west oriented stream that enters the Snoqualmie River just north of Duvall, approximately seven miles upstream of the river's confluence with the Skykomish River near Monroe. The routine sampling location receives drainage from approximately 8,531 acres of the overall subbasin and is approximately 2.2 stream miles above the confluence (Figure 1). The subbasin spans the border between King and Snohomish Counties, with roughly 70 percent of basin area in King County. Slightly less than 3 percent of the subbasin lies within the City of Duvall. Cherry Creek is known spawning and rearing habitat for coho salmon and steelhead trout. In addition, fall Chinook, summer steelhead, and pink salmon are known to use the system, and bull trout are presumed to use it (WDFW, 2014).

2.2.3 Griffin Creek

The sampling station on Griffin Creek receives drainage from 10,126 acres of a predominantly forested subbasin that generally flows in a southwesterly direction until it reaches the Snoqualmie River floodplain where it trends to the northwest for approximately three miles to its confluence with the Snoqualmie River (Kaje, 2009). Like many other tributaries in the watershed, the lowest reaches of Griffin Creek are within the agriculture production district (APD) which includes portions of the Snoqualmie's 100-year floodplain. Since these stream sections are more typical of the Snoqualmie River floodplain ecosystem, they are below our routine sampling locations. In Griffin Creek, the routine sampling location is approximately 2.3 stream miles upstream from the confluence with the river (Figure 1). The watershed also contains a rural residential land use designation, and King County's Griffin Creek Natural Area. In the forested reaches, riparian vegetation is primarily composed of native species (King County, 2002). Griffin Creek is known spawning and rearing habitat for coho salmon and steelhead trout. In addition, fall Chinook, fall chum and pink salmon, as well as summer steelhead, are known to use the system, and bull trout are presumed to use it (WDFW, 2014).

2.2.4 Harris Creek

The Harris Creek routine sampling location is approximately 1.6 stream miles above the confluence with the river and drains 5,301 acres comprised primarily of a broad upland terrace that features extensive wetlands as well as several lakes and ponds. Most of the subbasin is dominated by forestry land covers on both State- and privately owned forest lands (76 percent). Approximately 6 percent of the subbasin comprises rural residential land uses, with the remaining 18 percent in agriculture (Table 2). The highest residential densities are associated with the shoreline development of two small lakes in the drainage. The entire subbasin is served by on-site septic systems (Kaje, 2009).The documented distributions of coho salmon and both summer and winter steelhead extends into the upper watershed (WDFW, 2014) where extensive wetlands and ponds likely provide excellent rearing habitat (Kaje, 2009). Additionally, bull trout are thought to use most of the drainage (WDFW, 2104).

2.2.5 Middle Fork Snoqualmie River

The Middle Fork Snoqualmie is the largest subbasin in the Snoqualmie watershed, draining nearly 110,000 acres (Table 2). The routine sampling location is approximately 0.5 river miles upstream of the confluence with the North Fork Snoqualmie River (Figure 1). The three forks of the Snoqualmie River come together above the 270 feet high barrier to anadromy at Snoqualmie Falls. As a result, they lack salmon and steelhead, but do provide productive habitat for cutthroat trout and mountain whitefish (Overman, 2008). Similar to the other subbasins that form the eastern headwaters of the watershed, the Middle Fork Snoqualmie is mostly forested. The upper two thirds of the Middle Fork are within the Mount Baker-Snoqualmie National Forest (MBSNF), much of it within the Alpine Lakes Wilderness. In the lower reaches, apart from areas in close proximity to the City of North Bend, nearly all lands are within WDNR timber lands or in the Mount Si Natural Resource Conservation Area (NRCA). King County also owns roughly 644 acres along the Middle Fork in the Middle Fork Snoqualmie Natural Area (MFSNA). From its confluence with the North Fork, the first mile or so of the Middle Fork lies within the King County, Three Forks Natural Area. Cutthroat trout are distributed throughout the subbasin, including headwater tributaries, while rainbow trout are thought to occupy the mainstem up to approximately Rock Creek at river mile (RM) 28 (WDFW resident fish distribution data).

2.2.6 North Fork Snoqualmie River

The North Fork Snoqualmie River sampling location drains more than 66,000 acres that is almost entirely forested within a patchwork of federal, state, and private ownership (Table 2). The routine sampling station is located approximately 0.25 miles upstream of the confluence with the Middle Fork Snoqualmie River (Figure 1). As with the Middle Fork, this subbasin is above the falls and has no anadromous fish. The headwaters flow from the Alpine Lakes Wilderness near the crest of the Cascade Mountains. Land cover is mostly forest (78 percent), approximately 21 percent in agriculture, and less than 1 percent residential. Cutthroat trout have known distributions in headwater tributaries of the North Fork, while rainbow trout and non-native eastern brook trout are also found in lower elevation areas (Overman, 2008).

2.2.7 Patterson Creek

Patterson Creek drains nearly 13,000 acres and is the largest left bank tributary to the Snoqualmie River downstream of Fall City. The routine sampling location is located approximately 0.5 river miles upstream of the confluence with the mainstem Snoqualmie River (Figure 1). The subbasin has a broad elevation range from 70 feet above mean sea level to more than 1,400 feet in the headwaters (King County, 2004). The mainstem originates in a low-gradient upland catchment with many lateral wetlands that extend nearly the entire length of the stream from Redmond-Fall City Road to the Snoqualmie River confluence (King County, 2004). Patterson Creek flows in a southeasterly direction for most of its length before turning north and intersecting the Snoqualmie River's floodplain through farmland. Like many other tributaries in the watershed, the lower portions of Patterson Creek lie within an agriculture production district (APD).

Much of Patterson Creek is considered Core summer salmonid habitat by the WDFW that requires special thermal protections (Figure 2). Despite the important designation, fish habitat conditions in the mainstem of Patterson Creek are generally regarded as poor, owing to riparian degradation, fish passage barriers and a lack of large wood in the stream (Haring, 2002). In spite of relatively poor habitat conditions, salmonids are known to make extensive use of the Patterson Creek subbasin (Haring, 2002). Both winter steelhead and coho salmon use the mainstem and several key tributaries for both spawning and rearing. Fall Chinook, fall chum, and pink salmon are also known to utilize a substantial portion of the mainstem, and bull trout are suspected of using much of Patterson Creek (WDFW, 2014).

2.2.8 Raging River

The Raging River lies along the western edge of the Snoqualmie. The river generally flows in a northwesterly direction, joining the Snoqualmie River at Fall City where the routine sampling location is. The total drainage area is approximately 20,000 acres. Land use in the subbasin is primarily composed of forestry (83 percent of drainage), while low-density rural residential land use (3 percent), and other uses (14 percent) are more prevalent in the lower portions of the subbasin. The unincorporated towns of Preston and Fall City exhibit higher density residential areas as well as commercial and industrial uses. The Washington Department of Natural Resources owns and manages large blocks of forested lands in portions of the basin, including some areas classified as rural residential land-use under the King County Comprehensive Plan. Forested lands in the upper watershed are mostly under public ownership (King County, 2014). The Raging River is one of the core spawning areas for Chinook salmon as well as populations of steelhead trout and coho salmon (Table 3; Haring, 2002). Fall Chinook, coho, and winter steelhead are all known to spawn and rear in the system. In addition, fall chum, and odd year pink salmon, as well as summer steelhead are known to use the river and bull trout are thought to be present (WDFW 2014).

2.2.9 Snoqualmie River at Duvall

The Snoqualmie Mainstem sampling location (Figure 1) features diverse land uses in unincorporated areas as well as portions of the cities of Duvall, Carnation, and Snoqualmie. Excluding upstream watersheds sampled in this program, the mainstem Snoqualmie site drains nearly 68,000 acres and is located in the City of Duvall, downstream of the waste water treatment plant. Rural residential land use (8 percent), agriculture (28 percent), small-scale forestry and other (65 percent) activities take place in some of these areas. Below Snoqualmie Falls, nearly the entire floodplain is designated for agricultural land use. The floodplain itself is approximately one mile wide along much of the river and over two miles wide downstream of Duvall. The agricultural floodplain is drained by numerous ditches and tributaries that are tributary to the Snoqualmie (Kaje, 2009).

As a mainstem river, all anadromous fish species that are known to reside in the basin, including four species of salmon, winter and summer run steelhead, and bull trout spawn, rear, or are otherwise known or presumed to use the river (WDFW, 2014). Tributaries

within the floodplain provide rearing habitat and high-water refuge areas for juveniles of many species including Chinook salmon (Haring, 2002).

2.2.10 South Fork Snoqualmie River

The South Fork Snoqualmie originates near Snoqualmie Pass and flows more than 30 miles before joining the mainstem Snoqualmie River near the city of North Bend. Total contributing area above the sampling location is greater than 52,000 acres. For most of its length the South Fork follows Interstate 90. Most of the watershed is within the Mount Baker– Snoqualmie National Forest, and Olallie and Twin Falls Washington State Parks. The South Fork flows through North Bend before passing through King County-owned Tollgate Farm32, Mount Si Golf Course and a small portion of the Three Forks Natural Area at the confluence with the mainstem (Kaje, 2009). The routine sampling location on this fork is located in the city of Snoqualmie, just below their waste water treatment plant, approximately 2.2 river miles above the confluence with the mainstem (Figure 1).

Resident cutthroat trout, rainbow trout, and mountain whitefish are found in the mainstem and numerous tributaries to the South Fork, with cutthroat ascending into headwater areas. Again, because this stream is above Snoqualmie Falls, a barrier to anadromy, it does not receive supplemental thermal protections.

2.2.11 Tolt River

The Tolt River subbasin is one of the largest in the watershed. At 61,485 acres, it is larger than the South Fork Snoqualmie and roughly the same size as the North Fork Snoqualmie. The Tolt is significant and unique on a number of fronts. The South Fork Tolt reservoir is a core component of the regional water supply system. The Tolt River provides important spawning habitat for fall Chinook, coho, fall chum, and odd year pink salmon. In addition, both summer and winter steelhead spawn and rear in the system. Bull trout are also thought to rear throughout most of the system (WDFW, 2014). Also, the Tolt River is home to the only known naturally occurring spawning population of summer steelhead in WRIA 7. More than 83 percent of the basin is forested is in both public and private ownership (Table 2).

2.2.12 Skykomish River

Approximately 109,000 acres of the combined Foss, Tye, Beckler, and South Fork Skykomish rivers drain King County portions of the upper south fork Skykomish above the sampling site. Possibly owing to the relatively large extent of forest in the basin (Table 2), some of the healthiest aquatic habitat remaining in King County is in the Skykomish River drainage (King County, 2002). Our routine sampling location is relatively high in the drainage near the town of Skykomish (Figure 1). It contains populations of Chinook salmon and steelhead trout that are listed as “threatened” under the Endangered Species Act (ESA).

2.3 Water Quality Criteria

In the State of Washington, unless different designated uses are defined for a given water body (see e.g., WAC 173-201A; Table 602[3]), all surface waters are protected for salmonid spawning, rearing, and migration; primary contact recreation; domestic, industrial, and agricultural water supply; stock watering; wildlife habitat; harvesting; commerce and navigation; boating; and aesthetic values (WAC 173-201A). However, additional protections may create unique water quality requirements that are determined in part by the habitat requirements of the aquatic biota that spend all or part of their lives in a given system (Table 3). These state water quality standards[4] were updated in January 2011 to protect spawning, incubating, and rearing salmon, trout, and char (Payne, 2011; Table 3). Salmonid habitat receiving these supplemental protections must maintain a 7-day average of the daily maximum (7-DADMAX) temperature that remains consistent with known fish use (Figure 2; Table 3), DO greater than 8.0 mg/L, 6.5<pH>8.5, and total dissolved gas less than 110 percent of saturation for the periods of time fish are known to spawn and incubate in these segments (Table 3).

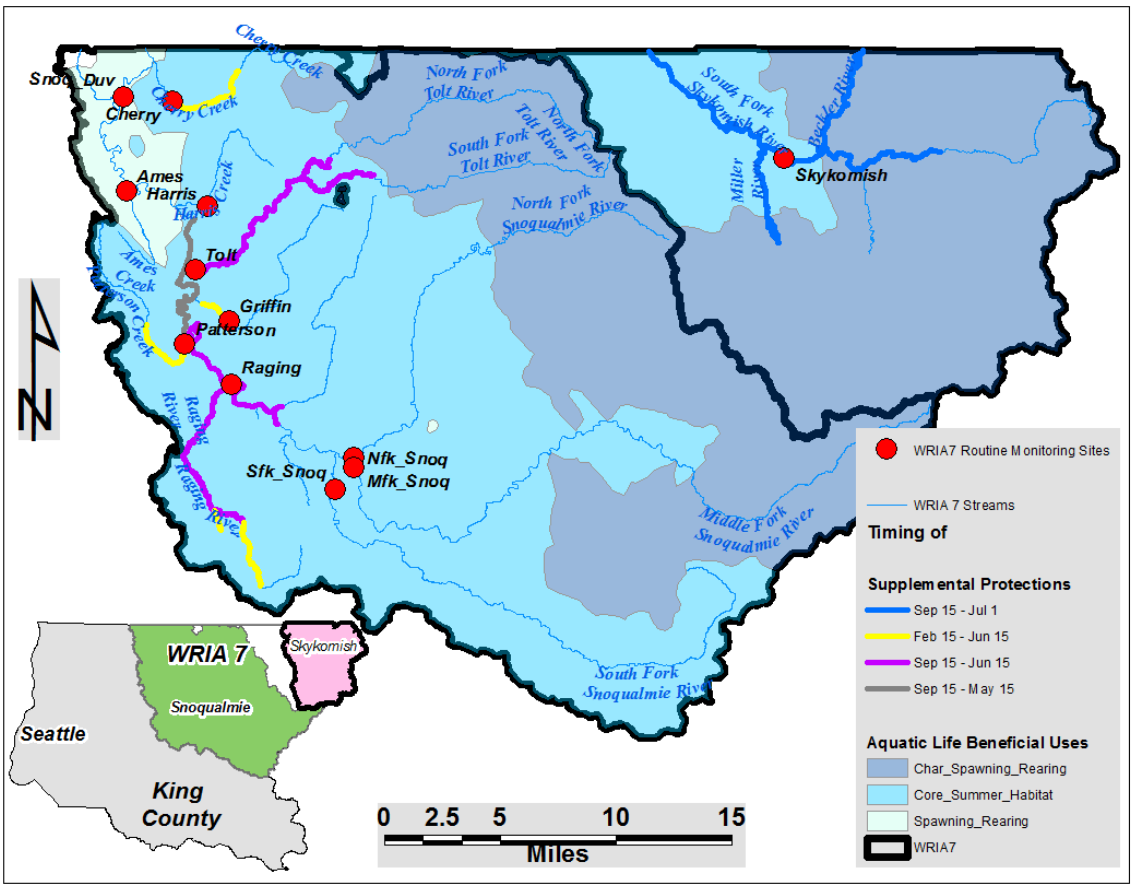

Figure 2. Distribution and timing of salmonid spawning and incubation that results in extended thermal protections in King County portions of the Snohomish Basin. Source: Washington State Department of Ecology.

[3] http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-602
[4] http://www.ecy.wa.gov/programs/wq/swqs/index.html

Trout, including steelhead are spring spawning fish, whereas salmon and char are fall spawners and their embryos incubate in stream gravels for a period of weeks to months. The known timing and geographic distribution of fish affects when streams receive these supplemental protective regulations (Figure 2; Table 3). Moreover, the species of fish and their habitat requirements determine the intensity of the supplemental protections. For example, the 7-DADMAX for rearing bull trout is 12°C and core summer habitat for other salmonids is 16°C (Figure 2; Table 3). In addition to fish, the "aquatic life designated uses and criteria" established in the water quality standards govern other criteria that directly affect human uses, and other aquatic organisms. These criteria include the 7-DADMAX, dissolved oxygen (DO), turbidity, pH, and fecal bacteria levels (Table 4). The results from this monitoring program can alert managers to potential problems that merit closer investigation.

In WRIA 7, nearly all the flowing waters in the watershed are affected by these supplemental criteria that supersede other water quality requirements while they are in effect (Table 3). In particular, the headwaters of most systems are designated by the state as "Char Spawning and Rearing" habitat including parts of the Skykomish River, both forks of the Tolt River, and parts of the North- and Middle-Forks of the Snoqualmie River (Figure 2, Table 3). Much of the western portion of the watershed is classified by the state as "Core Summer Habitat" (Figure 2). The remainder of the lower mainstem Snoqualmie River is classified by the state as "Spawning and Rearing" habitat. Each of these designations has specific water quality requirements (Table 3, Table 4). In addition, based on the timing of known fish use, supplemental water quality criteria may exist in specific sections of waters in WRIA 7 (Figure 2). Most of the "Salmon and Trout Spawning and Incubation" habitat protections in WRIA 7 begin on September 15 because they are used by char, salmon, and trout species. However, for those stream segments known to be used exclusively by cutthroat and rainbow trout, including steelhead, thermal protections begin on February 15. These protections extend through the time of year when known spawning and incubation, or other use of respective stream sections is concluded (i.e., May 15, June 15, and July 1; Figure 2; Table 3; Table 4).

Table 3. State of Washington water quality criteria that apply to WRIA 7 long-term monitoring stations according to human contact as well as supplemental aquatic life standards.

Aquatic Life Uses[¥]	Maximum 7-DADMAX	Effective Time Period [*]
Char Spawning and Rearing	53.6F (12C)	Sep 15 – Jul 1
Salmon and Trout Spawning Habitat	55.4F (13C)	Sep 15 – June 15, Feb 15 – June 15, Sep 15 – May 15
Core Summer Habitat	60.8F (16C)	Year Round

[*]Some upstream extents may have differing effective time periods for supplemental aquatic life criteria. See Figure 2 for geographic extent and effective time periods.
[¥]These temperature standards apply as per WAC 173-201A-602.

Table 4. State of Washington Designated selected water quality Criteria* affecting specific waters of WRIA 7 (See Figure 2).

Water Quality Criterion	Parameter	Numeric Value	Units
Supplemental Spawning and Incubation Protection for Salmonid Species	Dissolved Oxygen	9.5 mg/L for Char habitat designations and core summer salmonid habitats; 8.0 mg/L for Salmonid spawning, rearing, and migration habitats; and, 6.5 for Salmonid rearing and migration only habitats.	Lowest 1-day minimum
	pH	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.2 units for Char designated habitats and 0.5 units for other salmonid habitat designations.	
Human Contact	Turbidity	Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or A 10 percent increase in turbidity when the background turbidity is more than 50 NTU for Char habitat designations and a 20 percent increase for other salmonid designations.	
	Bacteria	For waters categorized as "Extraordinary Primary Contact Recreation"[5] fecal coliform organism levels must not exceed a geometric mean value of 50 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies /100mL. For waters designated as "Primary Contact Recreation"[6] fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100mL.	

*Source: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-600

[5] Extraordinary Primary Contact Recreation waters included in this program include: The Skykomish River at Skykomish, the North Fork and Middle Fork Snoqualmie rivers, and the Tolt River.
[6] Primary Contact Recreation waters involved in this program include the South Fork Snoqualmie River, the Snoqualmie River at Duvall, and all Snoqualmie River tributaries ***except*** the Tolt River.

2.4 Water Quality Index

The WQI integrates Washington State water quality standards with additional parameters in the form of a unitless rating of "high," "moderate," or "low" water quality concern (Hallock, 2002). The WQI facilitates rapid, objective comparisons among all sites and informs management responses to obvious problems. Because monthly grab samples cannot be evaluated according to some of the State water quality criteria, such 7-DADMAX, we employ the water quality index (WQI; Hallock, 2002). The WQI provides a synthesis of conditions for each watershed by combining various water quality measurements (Table 1) into a dimensionless number, allowing comparisons among time periods and streams. Sampling locations are evaluated based on WQI scores ranging from 0 to 100. Scores below 40 indicate generally poor water quality that are of "high concern." Scores between 40 and 80 are considered moderate water quality and are considered to be of "moderate concern." Good water quality receives WQI scores greater than 80 and are of low concern (Figure 3).

Water quality data are evaluated in the WQI based on water years (i.e., October 1 – September 30). Monthly sampling was begun in February, 2011. Unfortunately, when summarizing the data for the 2011 water year WQI estimates were based on a partial data record which may yield biased results compared to a full water year. Data for October 1, 2010 through January 31, 2011 were missing from the first year. By contrast, subsequent WQI estimates are based on complete water years. Water quality parameters were measured monthly to generate the WQI and included conventional parameters (Table 1).

Results for all the King County routine water quality monitoring data can be obtained at the Water Quality Index website. For temperature, pH, fecal coliform bacteria, turbidity, and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses according to criteria in Washington's Water Quality Standards, WAC 173-201A. For nutrient and sediment measures where there are no standards, results are expressed relative to other guidelines for this ecoregion following US EPA (2000).

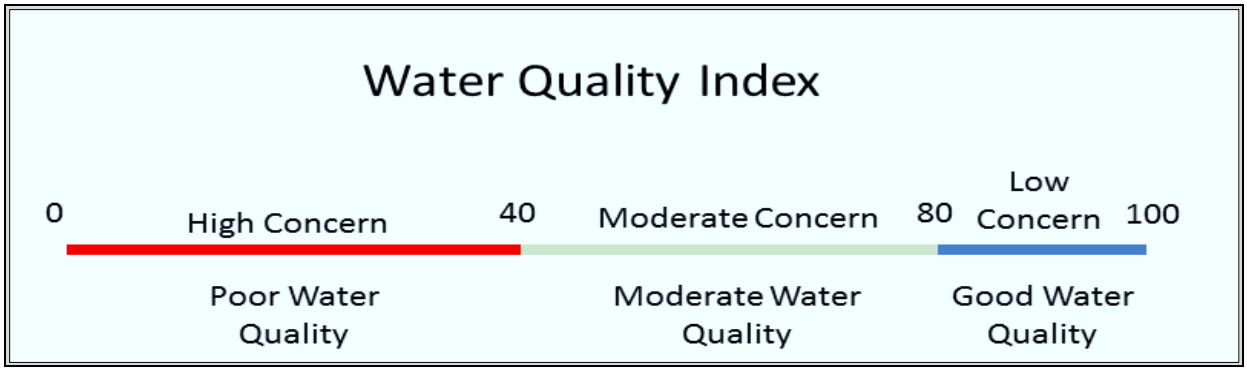

Figure 3. Range of conditions quantified with the water quality index (WQI) developed by the Washington State Department of Ecology (Hallock, 2002).

Scores below 40 are given to water ways of "high concern." Scores between 40 and 80 are assigned to waterways that are of "moderate concern," and waters receiving scores higher than 80 are considered to be in good condition.

3.0 RESULTS

3.1 Ames Creek

During 2011, Ames Creek was rated as of moderate concern with a WQI of 64. In 2012 and 2013 the WQI was estimated from complete water years and was 52 and 47, respectively. The WQI scores Ames Creek are in the low end of the "moderate concern" range. Ames Creek is classified as supporting "core summer rearing; spawning and migration," which affects the range of acceptable temperature and dissolved oxygen (DO) for this stream (60.8˚F (16˚C) 7-DADMAX, and minimum DO 9.5 mgL-1 (Figure 2). However, there are no supplemental water quality protections for Ames Creek. Fecal coliform (FC) bacterial levels and water temperature (T) look like they could be chronically problematic during warm months (Table 5). In addition, several pH measurements during spring months have been lower than State water quality criteria allow. These lower pH values may reflect a lack of landscape buffering capacity, effects of soil and land use, bacterial cycling of carbon, and heavy winter precipitation (Marsh, 1991).

Table 5. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in Ames Creek. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	19	9.2	6.3	0.1240	11.4	5.6	1.480	107	0.161	0.754	0.0686
3/11	54	10.2	6.7	0.1330	11.3	7.8	1.250	118	0.217	0.516	0.0815
4/11	48	10.1	6.8	0.0926	6.8	9.2	1.060	118	0.161	0.491	0.0558
5/11	180	9.2	6.6	0.0876	7.6	11.8	1.000	125	0.147	0.405	0.0490
6/11	190	8.5	6.9	0.1240	18	13.5	1.120	152	0.183	0.444	0.0521
7/11	190	9.1	7.5	0.0745	8.3	13.7	0.900	155	0.056	0.551	0.0479
8/11	160	9.0	7.5	0.0747	8.1	14.1	0.810	156	0.038	0.538	0.0701
9/11	260	8.3	7.5	0.0842	8.9	12.2	0.850	153	0.033	0.555	0.0539
10/11	290	9.4	7.0	0.1200	18	10.4	1.700	155	0.072	1.010	0.0489
11/11	220	8.2	6.5	0.1208	7	7.2	2.300	119	0.081	1.480	0.0481
12/11	13	10	6.8	0.0775	11.8	6.2	1.290	152	0.129	0.755	0.0473
1/12	23	10.6	6.4	0.0811	15.4	3.1	1.780	108	0.090	1.150	0.0485
2/12	12	9.8	6.8	0.0968	13.8	6.8	1.290	124	0.125	0.731	0.0536
3/12	29	10.8	6.4	0.1070	22.4	5.5	1.190	87.3	0.088	0.593	0.0541
4/12	27	9.5	6.7	0.0733	6.6	9.0	0.982	123	0.074	0.551	0.0370
5/12	130	9	6.9	0.0607	5.4	12.3	0.806	114	0.042	0.412	0.0293

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
6/12	480	7.2	7.0	0.0573	3.7	14.0	0.758	126	0.033	0.385	0.0320
7/12	140	8.7	7.2	0.0885	8.1	15.1	0.850	154	0.042	0.518	0.0482
8 /12	250	8.8	7.5	0.0677	4.7	14.8	0.708	162	0.022	0.479	0.0361
9/12	93	9.7	7.3	0.0584	6.1	11.0	0.729	156	0.022	0.539	0.0329
10/12	56	8.9	7.0	0.0823	8.6	7.9	1.350	156	0.041	0.665	0.0299
11/12	370	7.5	6.5	0.1720	43.2	6.6	1.800	114	0.115	0.736	0.0683
12/12	180	8.9	6.6	0.1690	23	6.3	1.690	99.7	0.137	0.883	0.0983
1/13	59	10.3	ND	0.0921	14.4	3.8	1.350	105	0.098	0.732	0.0400
2/13	10	9.6	6.6	0.0934	12.3	6.3	1.140	118	0.080	0.632	0.0416
3/13	52	9	6.4	0.0919	6.2	7.0	1.080	122	0.102	0.488	0.0530
4/13	120	9.2	6.4	0.1060	9.6	8.4	1.090	103	0.095	0.365	0.0570
5/13	72	9.4	7.0	0.0627	8.5	11.5	0.850	137	0.047	0.457	0.0293
6/13	110	9	7.4	0.0050	6.5	14.6	0.760	153	0.027	0.487	0.0390
7/13	230	8.6	7.1	0.0583	2.9	13.8	0.668	154	0.022	0.454	0.0356
8/13	210	8.5	7.3	0.0559	2.5	14.2	0.612	160	0.016	0.399	0.0389
9/13	260	7.1	7.0	0.0709	1.8	14.9	0.832	159	0.026	0.315	0.0397

*For more complete description of how these instantaneous measurements fit within the State of Washington water quality criteria, please see Table 3. ND = no data were collected.

Water Quality Data from Ames Creek can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Ames_1

3.2 Cherry Creek

Based on many studies conducted in the past fifteen years, including the most recent Washington State Department of Ecology (WDOE) TMDL Effectiveness report (WDOE, 2008), water quality in Cherry Creek is degraded relative to other Snoqualmie watershed tributaries (Kaje, 2009). However, data collected in this routine monitoring program indicate only one excursion outside of Washington water quality standards in July of 2011 for FC, and two excursions for water temperatures (T) during June 2011 and June 2013 (Table 6). The WQI scores (range 87-89) for this system suggest that water quality is in good condition. Some of the differences between routine monitoring results and other studies could be due to the location and timing of the sampling location and the proportions of upstream land covers in the contributing watershed (Table 1). Cherry Creek is designated by the state as core summer habitat for salmonids, and receives supplemental temperature protections from February 15 through June 15 owing to specific fish use of the system. During 2011, Cherry Creek was rated as of low concern with a WQI of 89. In 2012 and 2013 the WQI was estimated from complete water years and was 87 during both years.

Table 6. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013in Cherry Creek. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	4	13.1	7.0	0.0110	5.0	5.6	0.668	38.8	0.010	0.616	0.0036
3/11	16	12.1	7.4	0.0062	0.9	7.2	0.605	41.8	0.010	0.510	0.0034
4/11	1	11.7	7.3	0.0071	2.0	8.2	0.490	44.1	0.010	0.395	0.0030
5/11	20	10.7	7.3	0.0205	16.1	10.2	0.449	41.1	0.010	0.310	0.0023
6/11	39	10.2	7.4	0.0088	0.5	13.2	0.319	51.0	0.007	0.219	0.0046
7/11	210	10.3	7.7	0.0103	1.5	15.1	0.399	68.7	0.008	0.285	0.0076
8/11	45	9.9	7.6	0.0134	0.7	15.4	0.382	81.7	0.006	0.279	0.0096
9/11	64	10.0	7.6	0.0195	0.8	13.1	0.422	85.0	0.010	0.317	0.0145
10/11	11	11.3	7.4	0.0155	2.1	10.3	0.560	65.8	0.016	0.444	0.0090
11/11	14	12.2	7.1	0.0162	5.1	6.7	1.150	41.9	0.012	1.010	0.0066
12/11	5	12.4	7.1	0.0069	0.7	5.6	0.875	49.2	0.008	0.762	0.0048
1/12	4	13.1	7.0	0.0102	4.3	3.9	1.140	40	0.010	0.950	0.0031
2/12	11	11.7	7.2	0.0082	1.4	6.3	0.907	45.8	0.010	0.915	0.0039
3/12	ND	13.1	7.0	0.0072	4.3	5.3	0.869	36.2	0.010	0.785	0.0027
4/12	1	12.1	7.3	0.0053	1.3	8.4	0.564	44.1	0.010	0.479	0.0038
5/12	16	10.7	7.6	0.0065	1.4	12.4	0.496	48	0.010	0.376	0.0034
6/12	72	10.2	7.4	0.0110	5.3	12.1	0.362	39.7	0.010	0.190	0.0026
7/12	43	9.6	7.5	0.0119	1.4	16.4	0.397	59.6	0.008	0.207	0.0063

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
8/12	50	9.2	7.8	0.0178	0.9	16.9	0.374	82.3	0.009	0.262	0.0100
9/12	41	10.6	7.5	0.0271	7.7	12.4	0.466	88.5	0.010	0.323	0.0118
10/12	5	11.2	7.4	0.0104	1.0	7.1	0.685	60.1	0.010	0.561	0.0056
11/12	7	11.7	7.1	0.0125	4.2	6.7	0.905	39.7	0.009	0.681	0.0051
12/12	23	12.0	7.0	0.0182	9.4	6.4	0.749	34.2	0.006	0.660	0.0042
1/13	8	13.1	ND	0.0070	1.1	4.1	0.776	39.1	0.010	0.709	0.0041
2/13	1	11.8	7.1	0.0067	1.2	5.7	0.626	40.0	0.010	0.585	0.0035
3/13	2	12.7	7.1	0.0119	4.1	6.4	0.499	35.5	0.010	0.412	0.0036
4/13	5	12.0	7.1	0.0104	3.0	7.2	0.465	33.1	0.010	0.349	0.0030
5/13	14	10.7	7.5	0.0097	1.2	11.7	0.322	51.3	0.006	0.225	0.0041
6/13	41	9.4	7.6	0.0050	0.9	16.2	0.330	65.4	0.009	0.229	0.0070
7/13	32	9.4	7.3	0.0145	3.5	15.4	0.378	72.6	0.008	0.305	0.0094
8/13	26	9.7	7.4	0.0175	0.5	16.0	0.340	85.0	0.006	0.270	0.0135
9/13	90	9.4	7.5	0.0177	0.7	15.6	0.399	81.0	0.004	0.263	0.0112

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from Cherry Creek can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Cherry_1

3.3 Griffin Creek

More than 91 percent of the 11,000 acres of the Griffin creek watershed are forested upstream of the sampling location (Table 1). Griffin Creek is designated as core summer habitat for salmonids, and receives supplemental thermal protections from February 15 to June 15 (Figure 2). Compared to other tributaries in the lower watershed, Griffin Creek has good water quality, but the available historical data is very limited. The 2011 WQI rating for Griffin Creek was 89, which is in the "low concern" category indicating good water quality (Table 7). During 2012 and 2013, Griffin Creek WQI scores were 91 and 85, respectively. The water quality parameters that have sporadically indicated that there may be a problem are fecal coliform (FC), and water temperatures (T) exceeded the supplemental criteria twice during June 2011 and June 2013. Three times since 2011 there have been minor excursions above 100 cfu (Table 7).

Table 7. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013in Griffin Creek. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	0	11.8	7.1	0.0087	2.3	5.6	0.566	42.7	0.005	0.501	0.0042
3/11	0	11.9	7.5	0.0091	1.5	7.8	0.440	45.0	0.005	0.324	0.0042
4/11	3	11.1	7.4	0.0123	2.6	8.8	0.403	47.7	0.005	0.260	0.0050
5/11	2	10.5	7.3	0.0286	2.3	10.9	0.413	46.1	0.005	0.219	0.0041
6/11	15	10.0	7.6	0.0198	2.9	14.6	0.350	58.1	0.007	0.158	0.0070
7/11	47	10.0	7.7	0.0218	1.5	14.6	0.460	76.3	0.006	0.259	0.0122
8/11	18	9.7	7.6	0.0218	2.2	14.5	0.413	84.6	0.005	0.272	0.0147
9/11	160	9.8	7.6	0.0352	7.3	12.1	0.497	82.7	0.005	0.279	0.0164
10/11	41	10.7	7.4	0.0212	2.1	10.1	0.458	75.5	0.009	0.279	0.0090
11/11	33	12.2	7.3	0.0142	1.9	6.6	1.300	44.5	0.008	1.110	0.0042
12/11	1	12.4	7.2	0.0098	0.9	5.2	0.644	51.8	0.005	0.566	0.0057
1/12	8	13.4	7.0	0.0096	1.9	2.9	1.190	39.6	0.005	0.985	0.0030
2/12	5	11.9	7.3	0.0121	1.4	6.7	0.724	49.2	0.005	0.672	0.0047
3/12	2	13.2	7.0	0.0050	1.72	4.5	0.709	36.6	0.005	0.605	0.0026
4/12	13	10.5	7.5	0.0132	1.9	11.0	0.480	47.9	0.005	0.311	0.0043
5/12	1	10.1	7.5	0.0143	3.5	12.7	0.433	50.5	0.005	0.267	0.0047
6/12	45	9.8	7.5	0.0165	3.9	12.7	0.399	51.2	0.005	0.204	0.0066
7/12	29	9.4	7.4	0.0168	1.8	16.2	0.386	69.2	0.006	0.238	0.0101

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
8/12	24	10.2	7.7	0.0204	1.7	14.6	0.361	86.0	0.005	0.242	0.0112
9/12	10	10.4	7.5	0.0185	3.2	11.5	0.385	89.2	0.005	0.281	0.0145
10/12	9	11.7	7.6	0.0183	1	7.0	0.518	75.7	0.010	0.320	0.0077
11/12	5	11.9	7.3	0.0125	2.5	5.8	0.940	40.4	0.006	0.731	0.0052
12/12	8	12.0	7.1	0.0138	3.4	5.6	0.892	35.8	0.007	0.770	0.0272
1/13	10	13.4	ND	0.0088	1.3	2.4	0.802	41.7	0.010	0.713	0.0043
2/13	ND	12.6	7.3	0.0077	1.2	5.3	0.655	44.8	0.010	0.571	0.0050
3/13	5	12.1	7.3	0.0117	1.6	6.6	0.469	43.9	0.010	0.372	0.0058
4/13	7	12.0	7.2	0.0104	2.6	7.0	0.562	35.8	0.010	0.420	0.0044
5/13	13	10.5	7.4	0.0176	1.5	11.6	0.377	55.1	0.006	0.214	0.0068
6/13	11	9.3	7.5	0.0050	1.6	14.3	0.342	66.9	0.006	0.216	0.0091
7/13	200	9.5	7.4	0.0181	0.8	14.0	0.393	79.9	0.005	0.288	0.0129
8/13	17	10.2	7.5	0.0197	1.2	13.3	0.377	69.9	0.004	0.296	0.0150
9/13	170	9.6	7.5	0.0234	6.5	14.6	0.403	81.4	0.003	0.213	0.0118

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). Please see Table 3 for description of State water quality criteria. ND = no data were collected.

Water Quality Data from Griffin Creek can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Griffin

3.4 Harris Creek

According to 2011 routine monitoring results, water quality in Harris Creek appears to be in relatively good condition and within the range of conditions observed in other lowland subbasins (Table 8). Harris Creek is designated as core summer habitat for salmonid fishes (Figure 2). The only parameter that potentially raises concern is fecal coliform (FC). Water temperatures (T) during summer months also indicate slightly elevated temperatures. However, the rarity of high T, and FC values suggests they are likely not a problem when considered in the context of the State supplemental water quality criteria (Table 4). There was only one slight temperature excursion during June, 2013. In the past, nutrients were somewhat elevated in the lower portion of the basin. Likewise, dissolved oxygen has been shown to be low in the wetland-rich portions of the upper basin during summer months (Kaje, 2009). WQI scores for 2011 (partial water year), 2012, and 2013 were of "low concern" scoring 87, 86, and 92, respectively.

Table 8. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in Harris Creek. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate -Nitrite	Ortho Phosphate
2/11	14	12.8	7.1	0.0134	2.9	5.7	0.68	48.4	0.005	0.540	0.0045
3/11	1	11.8	7.5	0.0087	6.9	7.8	0.59	53.5	0.005	0.470	0.0044
4/11	7	11.3	7.4	0.0112	1.2	8.9	0.57	59.5	0.005	0.450	0.0044
5/11	17	10.6	7.4	0.1760	3.7	11.0	0.83	55.8	0.006	0.340	0.0050
6/11	23	10.2	7.5	0.0199	2.4	13.0	0.60	72.4	0.005	0.420	0.0092
7/11	51	9.7	7.6	0.0233	1.8	13.4	0.74	90.6	0.006	0.580	0.0140
8/11	27	9.7	7.5	0.0254	2.4	13.5	0.80	100.0	0.005	0.640	0.0171
9/11	330	10.1	7.6	0.0407	5.4	11.9	0.81	98.5	0.005	0.580	0.0245
10/11	17	11.2	7.5	0.0214	1.4	10.1	0.568	91.1	0.005	0.343	0.0108
11/11	34	12.2	7.3	0.0212	6.1	6.7	1.050	46.2	0.011	0.715	0.0042
12/11	32	12.5	7.2	0.0119	1.1	5.5	0.699	59.3	0.011	0.538	0.0072
1/12	7	13.3	7.1	0.0101	2.6	2.9	0.917	44.8	0.006	0.731	0.0033
2/12	5	11.7	7.4	0.0128	1.7	6.7	0.760	56.1	0.005	0.659	0.0050
3/12	4	13.1	7.1	0.0088	3.4	5.2	0.802	42.4	0.005	0.635	0.0047
4/12	9	11.4	7.4	0.0134	2.2	9.5	0.573	56.3	0.005	0.403	0.0053

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate -Nitrite	Ortho Phosphate
5/12	13	10.4	7.5	0.0160	2.9	12.4	0.581	60.2	0.005	0.413	0.0061
6/12	92	10.2	7.6	0.0214	4.9	12.5	0.567	61.7	0.005	0.331	0.0087
7/12	550	10.0	7.4	0.0216	2.2	14.7	0.629	78.6	0.005	0.486	0.0110
8/12	31	9.9	7.6	0.0279	2.0	14.0	0.742	99.0	0.005	0.634	0.0128
9/12	23	10.5	7.5	0.0199	1.6	11.5	0.749	101.0	0.005	0.610	0.0151
10/12	23	11.1	7.4	0.0264	4.2	6.8	0.626	91.1	0.011	0.353	0.0106
11/12	14	11.9	7.2	0.0128	2.7	6.2	0.751	42.8	0.009	0.482	0.0061
12/12	18	11.6	7.0	0.0211	10	6.0	0.698	38.9	0.009	0.554	0.0115
1/13	23	13.0	ND	0.0105	1.8	3.5	0.809	46.8	0.007	0.719	0.0050
2/13	4	11.2	7.3	0.0127	3.1	5.9	0.717	49.9	0.010	0.607	0.0051
3/13	10	12.3	7.3	0.0176	4.4	6.9	0.584	50.1	0.010	0.434	0.0056
4/13	7	12.0	7.3	0.0122	2.7	7.7	0.510	40.9	0.010	0.349	0.0043
5/13	15	10.6	7.5	0.0178	1.8	11.5	0.568	65.9	0.006	0.400	0.0081
6/13	14	10.3	7.5	0.0050	1.2	13.4	0.685	82.8	0.007	0.540	0.0121
7/13	44	9.7	7.4	0.0262	1.6	13.1	0.715	92.4	0.006	0.610	0.0272
8/13	52	10.0	7.5	0.0238	1.3	13.3	0.723	102.0	0.004	0.628	0.0192
9/13	33	9.4	7.5	0.0262	2.9	13.9	0.653	96.2	0.004	0.446	0.0177

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from Harris Creek can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Harris_1

3.5 Middle Fork Snoqualmie River

Much like the North Fork, the Middle Fork has very good water quality with the exception of some rare fecal coliform (FC) values and a single pH measurement that are slightly inconsistent with State water quality criteria (Table 9). For much of its length, the Middle Fork Snoqualmie is designated as core summer habitat for salmonids. However, the upper reaches are designated as char spawning and rearing (Figure 2). Estimates for the WQI indicate that the partial water year's data in 2011 biased the score up slightly when the WQI was 89. During 2012 and 2013, WQI was 77 and 75, respectively. Elevated levels of nutrients (Tot P, and Tot N) as well as isolated measurements of relatively high TSS, exhibited during the 2012 and 2013 water years may have contributed lower overall scores.

Table 9. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the Middle Fork Snoqualmie River. Respective water years are separated by horizontal lines.

Parameters* included Extraordinary Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	1	11.7	6.7	0.0196	18.2	4.6	0.127	18.7	0.005	0.110	0.0025
3/11	ND	12.5	7.2	0.0178	7.5	6.3	0.136	22.9	0.005	0.090	0.0005
4/11	5	12.1	7.0	0.0173	0.6	6.0	0.118	21.2	0.005	0.080	0.0024
5/11	2	12.1	6.9	0.0085	6.0	6.1	0.104	13.4	0.005	0.050	0.0005
6/11	1	11.3	7.0	0.0139	5.6	9.2	0.072	12.1	0.005	0.020	0.0005
7/11	7	10.5	7.2	0.0051	2.8	11.0	0.066	11.3	0.005	0.020	0.0005
8/11	4	9.6	7.3	0.0050	1.9	15.7	0.080	20.6	0.005	0.030	0.0005
9/11	100	9.6	7.4	0.0050	1.4	12.6	0.106	27.3	0.005	0.040	0.0005
10/11	5	11.3	7.2	0.0127	12.5	9.0	0.239	16.7	0.005	0.186	0.0020
11/11	2	11.8	6.9	0.0180	20.7	5.3	0.234	15.6	0.005	0.164	0.0020
12/11	1	12.5	7.2	0.0050	6.0	4.6	0.170	24.0	0.005	0.146	0.0020
1/12	1	12.5	7.0	0.0101	10.1	3.6	0.231	23.1	0.005	0.203	0.0020
2/12	1	12.2	7.2	0.0054	2.3	5.1	0.155	20.8	0.005	0.129	0.0020
3/12	1	13.4	6.5	0.0055	4.3	3.3	0.179	21.0	0.005	0.141	0.0020
4/12	8	11.6	6.9	0.0050	3.7	6.3	0.122	17.2	0.005	0.084	0.0022
5/12	43	11.5	6.6	0.0125	20.9	6.5	0.111	11.7	0.005	0.057	0.0023
6/12	110	11.8	7.3	0.0677	79.9	6.9	0.159	9.6	0.005	0.053	0.0020
7/12	14	10.9	6.9	0.0050	4.0	12.7	0.059	13.0	0.005	0.024	0.0020
8/12	14	8.9	7.1	0.0050	1.2	16.0	0.086	27.4	0.005	0.029	0.0020

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
9/12	25	9.3	6.9	0.0050	1.3	13.7	0.093	36.4	0.005	0.037	0.0023
10/12	4	11.8	7.5	0.0050	1.9	6.7	0.187	18.5	0.010	0.138	0.0005
11/12	ND	12.3	6.7	0.0065	5.2	4.4	0.188	16.8	0.010	0.145	0.0023
12/12	5	12.1	6.8	0.0203	8.2	4.0	0.249	21.6	0.010	0.191	0.0493
1/13	ND	13	ND	0.0050	0.7	1.9	0.205	22.2	0.010	0.170	0.0024
2/13	ND	12.2	6.8	0.0050	1.2	4.3	0.176	23.5	0.010	0.137	0.0005
3/13	ND	12.8	6.6	0.0143	7.0	3.4	0.144	14.3	0.010	0.101	0.0005
4/13	ND	12.5	6.5	0.0085	8.1	4.4	0.161	16.1	0.010	0.101	0.0005
5/13	3	11.8	6.4	0.0062	3.4	6.6	0.076	12.4	0.010	0.039	0.0005
6/13	14	11.0	6.8	0.0050	2.7	10.2	0.050	11.6	0.010	0.020	0.0005
7/13	19	9.0	6.6	0.0050	0.6	16.1	0.071	21.8	0.004	0.031	0.0017
8/13	18	8.7	6.8	0.0050	0.6	16.3	0.092	32.3	0.006	0.035	0.0033
9/13	160	8.8	7.0	0.0142	3.1	15.9	0.169	32.4	0.005	0.087	0.0027

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Middle Fork of the Snoqualmie River can be found at: http://green.kingcounty.gov/WLR/Waterres/StreamsData/Conventional.aspx?Locator=MFk_Snq

3.6 North Fork Snoqualmie River

For much of its length, the North Fork Snoqualmie is designated as core summer habitat for salmonids. However, the upper reaches are designated as char spawning and rearing (Figure 2). Sampling results indicate that water quality is generally very good in the North Fork, except for rare excursions outside of Washington water quality criteria for FC, and DO (Table 10). Historic water quality data are limited to a small number of sites in the lowest reaches of the river and suggest that high water temperature can be a concern during summer months (Kaje, 2009). However, data from this monitoring program have not shown temperature to vary widely from State water quality criteria. In part, that may be because once-monthly sampling misses the moments when temperature is problematic. The WQI scores were 76, 86, and 71 for water years 2011 (partial year), 2012, and 2013, respectively. The data suggest that intermittently elevated fecal coliform bacteria concentrations during 2011 and 2013 may be implicated in the lower WQI during those years.

Table 10. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the North Fork Snoqualmie River. Respective water years are separated by horizontal lines.

Parameters* included Extraordinary Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	C1on d	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	2	11.7	6.9	0.0261	24.4	5.0	0.26	31.9	0.005	0.238	0.0024
3/11	340	12.0	7.3	0.0082	3.6	6.9	0.34	41.3	0.005	0.291	0.0026
4/11	160	12.1	7.2	0.0058	9.0	6.2	0.26	33.6	0.005	0.210	0.0020
5/11	14	11.7	7.0	0.0073	2.6	7.4	0.23	27.7	0.005	0.166	0.0020
6/11	14	10.8	7.1	0.0051	1.6	10.4	0.16	21.9	0.005	0.093	0.0210
7/11	10	9.5	7.1	0.0050	1.3	12.1	0.14	21.1	0.005	0.089	0.0020
8/11	12	9.5	7.2	0.0174	0.5	14.4	0.25	40.4	0.005	0.178	0.0020
9/11	80	8.4	7.2	0.0050	1.8	11.8	0.28	46.5	0.005	0.223	0.0020
10/11	5	11.5	7.0	0.0050	2.3	9.0	0.212	23.1	0.005	0.151	0.0020
11/11	30	12.3	7.0	0.0096	5.7	5.4	0.278	23.2	0.005	0.214	0.0050
12/11	1	11.8	7.1	0.0050	0.5	5.3	0.274	35.5	0.005	0.243	0.0020
1/12	1	12.2	7.0	0.0050	1.0	4.3	0.312	31.6	0.005	0.272	0.0020
2/12	1	11.7	7.1	0.0050	0.5	5.3	0.261	31.2	0.005	0.245	0.0020
3/12	4	12.9	6.6	0.0050	0.9	3.8	0.324	34.5	0.005	0.279	0.0020
4/12	5	11.6	7.1	0.0050	0.6	6.6	0.242	27.0	0.005	0.206	0.0020
5/12	3	11.3	6.6	0.0058	4.5	7.5	0.194	19.0	0.005	0.123	0.0050
6/12	24	11.6	6.9	0.0130	15.6	6.9	0.185	15.4	0.005	0.093	0.0020
7/12	10	10.9	6.9	0.0050	1.1	13.8	0.156	26.7	0.005	0.116	0.0020

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	C1on d	Ammonia	Nitrate-Nitrite	Ortho Phosphate
8/12	14	9.2	7.0	0.0050	0.6	14.1	0.304	56.1	0.005	0.259	0.0020
9/12	23	8.8	6.7	0.0050	0.6	11.7	0.330	61.7	0.005	0.282	0.0022
10/12	5	11.4	7.4	0.0050	0.9	7.1	0.241	25.8	0.010	0.178	0.0005
11/12	2	12.2	6.7	0.0094	6.9	5.0	0.276	26.6	0.010	0.215	0.0024
12/12	10	11.5	6.7	0.0075	1.9	5.1	0.387	33.7	0.010	0.286	0.0034
1/13	4	12.5	ND	0.0050	0.5	3.1	0.306	35.0	0.010	0.290	0.0021
2/13	2	12.0	6.8	0.0050	0.7	4.8	0.323	38.9	0.010	0.287	0.0005
3/13	2	13.3	6.8	0.0061	2.9	3.9	0.206	23.3	0.010	0.179	0.0005
4/13	5	12.2	6.7	0.0050	1.4	5.1	0.276	28.4	0.010	0.206	0.0005
5/13	440	11.6	6.5	0.0172	0.5	7.6	0.258	21.7	0.061	0.136	0.0139
6/13	8	10.9	6.9	0.0050	0.9	10.8	0.120	22.0	0.010	0.092	0.0005
7/13	22	8.2	6.5	0.0050	0.5	14.7	0.239	43.7	0.002	0.208	0.0010
8/13	37	7.9	6.6	0.0056	0.5	14.0	0.279	57.3	0.003	0.272	0.0022
9/13	53	7.9	6.8	0.0050	0.5	14.1	0.303	49.0	0.002	0.234	0.0012

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Middle Fork of the Snoqualmie River can be found at: http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=NFk_Snq

3.7 Patterson Creek

Patterson Creek is designated as core summer rearing habitat for salmonids, and some lower reaches receive supplemental thermal protections during February 15 through June 15 (Figure 2). Outside of the King County designated agricultural production districts (APD), Patterson Creek is one of the most rapidly developing subbasins in the Snoqualmie Watershed (Haring, 2002). Historically, Patterson Creek has exhibited water quality impairment, including low dissolved oxygen, high water temperatures, fecal coliform bacteria, and nutrients (Kaje, 2009). During 2011 (partial water year), water quality was generally high, with one notable excursion from state water quality standards in terms of bacteria on September 26 and one minor excursion from supplemental temperature criteria during June, 2013 (Table 11). Overall that year, the WQI was higher than subsequent years with a value of 76. During 2012 and 2013, WQI was 66, and 67, respectively. Relatively high levels of fecal coliform bacteria (FC), as well as some potentially elevated levels of nutrients may be culpable for contributing to the "moderate concern" category exhibited in Patterson Creek.

Table 11. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in Patterson Creek. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	9	10.5	6.8	0.0461	9.2	6.0	1.15	86.7	0.0135	0.806	0.0152
3/11	4	9.9	7.1	0.0345	5.0	8.1	0.93	106.0	0.0144	0.653	0.0145
4/11	17	9.5	7.2	0.0382	1.4	9.0	0.87	120.0	0.0128	0.615	0.0163
5/11	20	9.2	7.1	0.0451	3.8	11.3	0.86	116.0	0.0143	0.555	0.0264
6/11	36	9.7	7.4	0.0606	5.3z	13.7	0.94	151.0	0.0201	0.615	0.0267
7/11	44	10.0	7.6	0.0483	3.5	14.2	1.00	175.0	0.0170	0.773	0.0316
8/11	66	10.1	7.7	0.0461	3.0	14.6	1.01	174.0	0.0113	0.793	0.0298
9/11	700	8.6	7.5	0.0559	2.6	12.4	0.96	168.0	0.0103	0.716	0.0376
10/11	38	9.6	7.3	0.0595	7.3	10.8	0.856	158.0	0.019	0.453	0.0273
11/11	41	9.5	6.8	0.0526	5.9	7.2	1.510	89.5	0.019	0.975	0.0178
12/11	69	11.3	7.2	0.0407	3.7	6.1	0.999	138.0	0.032	0.728	0.0254
1/12	15	11.7	6.7	0.0372	9.6	2.9	1.430	79.8	0.009	1.020	0.0119
2/12	16	10.4	7.1	0.0402	4.7	7.4	0.998	117.0	0.023	0.794	0.0229
3/12	4	10.8	6.6	0.0394	9.8	4.9	1.000	71.9	0.007	0.657	0.0111
4/12	47	7.8	7.3	0.0340	3.4	10.5	0.839	116.0	0.007	0.575	0.0154
5/12	50	9.6	7.3	0.0378	2.1	11.2	0.886	127.0	0.016	0.620	0.0181
6/12	74	8.3	7.2	0.0529	107.0	12.8	0.960	143.0	0.021	0.603	0.0288

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
7/12	32	9.3	7.4	0.0434	4.5	14.9	0.875	168.0	0.014	0.721	0.0256
8/12	80	9.1	7.6	0.0420	2.2	14.7	0.892	180.0	0.012	0.694	0.0162
9/12	210	9.5	7.4	0.0753	36.1	11.5	0.986	179.0	0.015	0.722	0.0248
10/12	130	9.9	7.3	0.0576	3.4	8.1	0.900	157.0	0.016	0.356	0.0265
11/12	18	8.6	6.7	0.0447	6.0	6.7	1.160	77.9	0.015	0.625	0.0166
12/12	140	10.3	6.7	0.0510	9.4	5.8	1.140	68.4	0.011	0.753	0.0160
1/13	8	11.9	ND	0.0321	5.5	2.7	1.070	87.9	0.017	0.852	0.0146
2/13	3	11.0	7.1	0.0324	3.7	6.1	0.918	106.0	0.018	0.706	0.0174
3/13	14	10.8	7.0	0.0446	7.2	7.3	0.826	112.0	0.017	0.578	0.0236
4/13	68	9.8	6.8	0.0393	7.2	7.4	0.835	74.3	0.009	0.466	0.0131
5/13	17	10.0	7.3	0.0470	3.0	11.0	0.885	140.0	0.009	0.548	0.0197
6/13	80	10.0	7.5	0.0050	2.5	13.6	0.888	170.0	0.010	0.667	0.0248
7/13	100	8.8	7.3	0.0459	4.0	13.6	0.920	174.0	0.010	0.706	0.0223
8/13	190	8.6	7.4	0.0465	5.0	13.7	0.947	182.0	0.009	0.715	0.0296
9/13	600	8.5	7.3	0.0815	0.9	14.0	0.949	171.0	0.024	0.516	0.0397

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from Patterson Creek can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Patter_3

3.8 Raging River

Historically, water quality conditions in the Raging River have been compromised by high temperature in the lower river during summer months. And yet, the state has designated the Raging River as core summer habitat for salmonids. In addition, there are supplemental thermal protections on this system from September 15 through June 15 in the lower reaches, while some upper reaches receive supplemental protections from February 15 through June 15 (Figure 2). High temperatures, pH, and fecal coliform concentrations have led to listings on the State's 303(d) list for impaired waterways (WDOE, 2008). During routine streams monitoring begun in 2011, water quality in the Raging River seems to be consistent with other stations in the basin (Table 12). Rare excursions for fecal coliform bacteria (FC), dissolved oxygen (DO), and temperature (T) have occurred, mainly during summer months. During 2011 (partial water year), 2012, and 2013, WQI scores for the Raging River were 67, 83, and 82, respectively. Intermittently high fecal coliform bacteria concentrations and seasonally high pH values are likely contributors to lower WQI values that might otherwise be indicated.

Table 12. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the Raging River. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	5	11.8	7.1	0.0210	28.5	5.7	0.50	36.0	0.005	0.478	0.0042
3/11	1	12.2	7.3	0.0116	6.9	7.0	0.44	37.5	0.005	0.391	0.0035
4/11	7	12.0	7.3	0.0134	5.8	7.6	0.34	39.7	0.005	0.273	0.0044
5/11	30	11.4	8.2	0.005	2.6	9.7	0.24	40.9	0.005	0.153	0.0020
6/11	35	10.9	8.3	0.005	2.5	12.9	0.27	43.3	0.005	0.162	0.0020
7/11	33	10.7	8.8	0.0060	1.9	15.9	0.20	64.3	0.006	0.057	0.0025
8/11	140	10.7	9.4	0.0061	1.1	17.8	0.19	82.2	0.008	0.065	0.0037
9/11	350	10.1	8.3	0.0159	2.2	13.1	0.32	80.1	0.005	0.201	0.0084
10/11	14	11.5	7.6	0.0081	2.9	9.9	1.450	44.3	0.010	1.360	0.0040
11/11	1	12.3	7.2	0.0099	4.4	6.8	1.110	36.3	0.005	1.000	0.0031
12/11	10	12.6	7.7	0.0050	0.5	5.9	0.642	55.4	0.005	0.611	0.0049
1/12	6	12.6	7.1	0.0072	3.2	4.9	1.010	47.3	0.005	0.870	0.0024
2/12	28	12.0	7.3	0.0068	2.4	6.2	0.625	44.1	0.005	0.642	0.0036
3/12	3	13.4	6.9	0.0050	3.0	3.9	0.639	36.0	0.005	0.561	0.0030
4/12	31	11.2	7.4	0.0185	23.5	8.5	0.462	42.1	0.005	0.366	0.0042
5/12	50	11.0	7.5	0.0053	1.9	10.9	0.398	51.5	0.005	0.281	0.0027
6/12	260	10.6	7.6	0.0133	11.1	11.1	0.385	40.7	0.005	0.238	0.0030
7/12	39	9.8	7.7	0.0089	1.5	16.2	0.329	62.2	0.010	0.218	0.0050

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
8/12	56	10.2	8.7	0.0072	1.1	16.2	0.171	83.8	0.007	0.074	0.0027
9/12	25	10.2	7.7	0.0051	1.2	12.5	0.161	94.3	0.005	0.079	0.0025
10/12	72	11.9	7.5	0.0106	1.3	6.4	1.060	64.8	0.010	0.899	0.0039
11/12	ND	12.3	7.2	0.0064	2.1	6.0	0.880	37.3	0.010	0.720	0.0037
12/12	20	12.0	7.0	0.0194	1.6	6.0	0.792	31.8	0.010	0.642	0.0042
1/13	ND	13.2	ND	0.0056	0.8	2.9	0.621	39.2	0.010	0.578	0.0036
2/13	5	12.2	7.1	0.0064	1.1	5.1	0.539	40.3	0.010	0.492	0.0030
3/13	1	13.0	7.0	0.0074	1.3	5.1	0.450	33.8	0.010	0.384	0.0036
4/13	10	12.4	7.0	0.0075	4.2	5.8	0.458	29.4	0.010	0.373	0.0026
5/13	19	11.7	7.7	0.0085	2.5	10.0	0.248	44.7	0.010	0.163	0.0005
6/13	19	10.9	8.6	0.0050	2.3	14.0	0.192	58.3	0.005	0.096	0.0005
7/13	54	9.2	7.4	0.0101	1.0	16.0	0.260	80.1	0.010	0.162	0.0042
8/13	73	9.6	7.7	0.0087	1.3	15.5	0.177	94.9	0.007	0.079	0.0044
9/13	140	9.5	7.8	0.0146	1.9	15.5	0.314	91.4	0.003	0.173	0.0051

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Raging River can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Raging_mth

3.9 South Fork Snoqualmie River

The City of North Bend's wastewater treatment plant is located approximately 2.2 river miles above the confluence with the mainstem Snoqualmie River. The routine water quality sampling location is just below the wastewater treatment outfall. Water quality in the South Fork Snoqualmie River has hovered between "moderate" and "low" concern. Some high fecal coliform bacteria (FC) concentrations and relatively high nutrients may be implicated in the slightly depressed WQI scores (Table 13). The WQI threshold for "low concern" is 80, and WQI scores for 2011 (partial year), 2012, and 2013 were 78, 78, and 81, respectively. For much of its length, the South Fork Snoqualmie is designated as core summer habitat for salmonids (Figure 2).

Table 13. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the South Fork Snoqualmie River. Respective water years are separated by horizontal lines.

Parameters* included Extraordinary Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	1	11.2	6.8	0.0102	2.2	5.5	0.407	56.4	0.101	0.284	0.0080
3/11	1	11.6	7.1	0.0051	1.1	7.1	0.359	73.0	0.006	0.317	0.0038
4/11	17	11.5	7.0	0.0180	5.9	7.0	0.361	63.9	0.063	0.253	0.0087
5/11	2	11.2	6.7	0.0057	0.9	6.6	0.222	36.4	0.027	0.160	0.0052
6/11	2	11.1	7.0	0.0122	1.1	9.4	0.189	35.3	0.032	0.097	0.0092
7/11	10	10.4	7.2	0.0316	0.8	11.7	0.288	48.5	0.079	0.128	0.0274
8/11	17	10.2	7.2	0.0124	0.5	13.9	0.339	76.0	0.043	0.214	0.0095
9/11	3500	9.4	7.1	0.0832	6.7	11.9	0.501	76.3	0.068	0.279	0.0619
10/11	1100	10.9	7.0	0.0528	0.7	8.8	0.503	47.5	0.180	0.275	0.0475
11/11	6	12.0	6.9	0.0294	1.0	5.6	0.483	60.0	0.043	0.347	0.0222
12/11	14	11.7	7.0	0.0050	0.5	6.1	0.344	76.7	0.023	0.305	0.0055
1/12	21	11.2	6.9	0.0381	0.9	5.4	0.626	76.8	0.217	0.366	0.0292
2/12	14	11.1	7.0	0.0174	0.7	6.1	0.573	71.4	0.270	0.333	0.0120
3/12	ND	11.9	6.7	0.0246	0.7	4.8	0.695	77.5	0.223	0.316	0.0087
4/12	30	11.2	6.9	0.0119	1.7	6.7	0.343	52.2	0.060	0.227	0.0085
5/12	4	11.4	6.8	0.0101	1.5	6.3	0.206	30.1	0.016	0.137	0.0081
6/12	95	11.7	6.9	0.0088	3.0	7.4	0.177	27.0	0.010	0.102	0.0075
7/12	25	10.2	6.9	0.0063	1.0	12.3	0.210	51.3	0.008	0.151	0.0040
8/12	23	9.4	7.0	0.0919	1.8	12.9	0.629	83.0	0.009	0.542	0.0811
9/12	20	9.2	6.8	0.1120	0.6	11.2	0.748	91.8	0.006	0.652	0.0889

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
10/12	13	11.0	7.2	0.0466	0.8	7.4	0.641	61.5	0.005	0.575	0.0447
11/12	13	11.5	6.8	0.0164	0.8	5.4	0.465	44.9	0.010	0.380	0.0139
12/12	14	11.0	6.8	0.0157	1.3	5.2	0.538	61.4	0.006	0.503	0.0155
1/13	8	11.7	ND	0.0546	0.5	4.1	0.550	69.7	0.128	0.370	0.0483
2/13	1	11.1	6.8	0.0181	0.5	5.5	0.558	74.5	0.007	0.514	0.0144
3/13	4	12.3	6.7	0.0823	1.0	4.2	0.366	51.5	0.115	0.222	0.0801
4/13	2	11.6	6.7	0.0112	0.8	5.1	0.352	55.3	0.033	0.244	0.0075
5/13	6	11.2	6.7	0.0050	0.6	7.0	0.171	38.5	0.010	0.119	0.0005
6/13	32	11.1	6.9	0.0050	0.9	10.2	0.291	44.3	0.142	0.111	0.0223
7/13	14	9.0	6.7	0.0114	0.5	13.1	0.319	73.5	0.009	0.247	0.0074
8/13	32	9.3	6.8	0.0751	0.5	12.5	0.544	90.2	0.008	0.492	0.0694
9/13	310	8.8	6.9	0.0930	0.9	13.2	0.787	89.4	0.005	0.587	0.0717

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the South Fork of the Snoqualmie River can be found at: http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=SFk_Snq

3.10 Snoqualmie River at Duvall

In general, water quality in the mainstem is of "low concern" according to the WQI. Historically, high temperature has been a problem, and certain areas have had chronic dissolved oxygen and pH problems (Kaje, 2009). However, WQI for 2011 (partial year), 2012, and 2013 all indicate excellent water quality yielding scores of 90, 91, and 81, respectively. The dip in WQI during 2013 might be explained by high fecal coliform concentrations and a relatively high temperature on the August sampling date and relatively low dissolved oxygen during July, August, and September (Table 14). The Snoqualmie River between Duvall and Snoqualmie Falls is designated as spawning and rearing habitat in the lower sections, and as core summer habitat for salmonids higher in the system. In addition, above the confluence with Harris Creek, supplemental thermal protections are in place from September 15 to March 15 up to Patterson Creek, and from September 15 to June 15 up to the falls (Figure 2). However, the upper reaches are designated as char spawning and rearing (Figure 2).

Table 14. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the Snoqualmie River at Duvall. Respective water years are separated by horizontal lines.

Parameters* included Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/15	4	11.8	6.7	0.0259	21.9	5.9	0.358	44.0	0.010	0.302	0.0046
3/28	3	11.5	7.0	0.0119	6.0	7.1	0.388	51.6	0.008	0.295	0.0038
4/25	5	11.3	6.9	0.0163	8.9	8.4	0.332	51.3	0.008	0.266	0.0038
5/23	6	11.5	6.8	0.0118	9.7	8.0	0.210	29.9	0.007	0.147	0.0026
6/27	5	10.6	6.9	0.0120	9.0	11.3	0.155	29.6	0.005	0.095	0.0081
7/25	14	9.8	7.2	0.0124	9.3	14.4	0.166	31.8	0.005	0.095	0.0032
8/22	14	9.0	7.0	0.0180	8.6	17.2	0.211	53.3	0.007	0.141	0.0055
9/26	64	8.9	7.2	0.0162	2.9	15.0	0.289	61.8	0.008	0.197	0.0087
10/11	150	10.7	7.2	0.0385	28.4	10.0	0.372	25.2	0.015	0.264	0.0051
11/11	31	12.7	6.9	0.0590	49.8	6.2	0.387	27.7	0.006	0.277	0.0033
12/11	5	11.7	6.9	0.0083	4.3	5.3	0.357	49.6	0.009	0.292	0.0064
1/12	10	12.6	6.9	0.0198	15.4	3.5	0.563	44.2	0.009	0.426	0.0050
2/12	1	11.3	7.0	0.0112	6.6	6.2	0.343	44.8	0.006	0.317	0.0038
3/12	1	12.5	6.8	0.0116	8.3	5.1	0.445	45.6	0.005	0.372	0.0041
4/12	16	11.7	7.0	0.0183	19.3	8.0	0.267	34.3	0.005	0.189	0.0033
5/12	24	10.3	7.1	0.0138	7.2	11.1	0.224	30.6	0.005	0.153	0.0031
6/12	1	11.3	7.3	0.0424	57.5	9.6	0.211	33.3	0.005	0.090	0.0094
7/12	3	9.7	6.8	0.0100	6.0	15.1	0.168	35.9	0.005	0.110	0.0039

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
8/12	10	9.0	7.4	0.0160	2.5	18.0	0.247	63.8	0.006	0.152	0.0055
9/12	11	9.6	7.3	0.0139	1.7	15.4	0.223	75.3	0.006	0.153	0.0088
10/12	60	10.0	7.1	0.0137	7.0	10.0	0.322	35.0	0.010	0.224	0.0035
11/12	14	11.2	6.9	0.0182	11.2	6.3	0.449	35.5	0.006	0.313	0.0075
12/12	41	11.5	7.0	0.0734	6.8	5.3	0.456	47.4	0.010	0.400	0.0063
1/13	1	13.0	ND	0.0103	4.0	2.7	0.439	47.3	0.009	0.391	0.0057
2/13	2	11.3	6.9	0.0089	2.4	5.5	0.389	50.6	0.009	0.343	0.0057
3/13	7	13.2	6.8	0.0212	19.7	4.8	0.241	29.4	0.007	0.196	0.0044
4/13	36	11.7	6.9	0.0169	12.3	6.6	0.328	35.6	0.005	0.237	0.0041
5/13	3	11.0	6.8	0.0113	4.9	9.3	0.160	29.4	0.005	0.121	0.0030
6/13	14	9.9	6.9	0.0050	3.7	13.6	0.136	31.2	0.010	0.091	0.0030
7/13	18	8.5	7.0	0.0148	0.5	17.3	0.193	54.0	0.006	0.141	0.0074
8/13	550	7.9	7.2	0.0158	1.1	18.8	0.224	68.3	0.009	0.148	0.0081
9/13	41	7.8	7.2	0.0239	1.7	16.3	0.288	70.9	0.029	0.154	0.0157

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Snoqualmie River at Duvall can be found at: http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=SnqDuvall

3.11 Tolt River

The Tolt River is classified by the state as core summer habitat in roughly the lower half of the system. Above the forks to the top of the drainage, the system is designated as char spawning and rearing habitat. In addition, from the confluence with the Snoqualmie to just above the forks, the Tolt River receives supplemental thermal protections from September 15 through June 15 (Figure 2).

During 2011 (partial year), 2012, and 2013 water quality in the Tolt River was very good (Table 14). The WQI exhibited "low concern" with scores of 89, 85, and 92, respectively. The geology of the basin, combined with historical and current forestry practices have resulted in a history of landslides and erosion, with likely impacts on turbidity, particularly during high flows (Kaje, 2009). However, in the routine monthly data collected in this monitoring program, suspended sediment was not indicative of water quality problems with the exception of a few substantial increases in total suspended sediment (TSS); most monthly measurements were consistent with other stations in the program (Table 15).

Table 15. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the Tolt River. Respective water years are separated by horizontal lines.

Parameters* included Extraordinary Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate-Nitrite	Ortho Phosphate
2/11	2	11.7	7.0	0.0101	9.9	5.3	0.342	37.7	0.005	0.310	0.0035
3/11	4	12.4	7.5	0.0062	4.5	6.8	0.373	43.5	0.012	0.323	0.0738
4/11	3	12.1	7.3	0.0073	2.6	7.0	0.329	41.3	0.005	0.284	0.0020
5/11	1	11.4	7.3	0.0086	4.2	8.5	0.272	34.4	0.005	0.205	0.002
6/11	6	11.2	7.5	0.0050	4.4	11.0	0.196	33.9	0.005	0.129	0.002
7/11	11	10.6	7.6	0.0050	4.1	12.5	0.224	38.8	0.005	0.167	0.002
8/11	4	10.6	7.8	0.0050	1.2	14.6	0.259	47.8	0.005	0.191	0.002
9/11	160	10.5	7.6	0.0050	1.4	11.2	0.306	45.8	0.008	0.232	0.0020
10/11	32	11.4	7.5	0.0102	5.8	9.3	0.363	35.5	0.017	0.276	0.0045
11/11	3	12.4	7.1	0.0215	21.6	6.0	0.398	31.6	0.005	0.320	0.0024
12/11	5	12.6	7.4	0.0050	1.2	5.7	0.372	47.0	0.005	0.352	0.0031
1/12	3	13.0	7.2	0.0090	10.4	4.1	0.436	38.0	0.005	0.364	0.0025
2/12	1	12.1	7.2	0.0054	2.6	5.7	0.347	37.5	0.005	0.341	0.0020
3/12	3	13.1	7.0	0.0105	5.0	4.5	0.484	39.0	0.005	0.418	0.0027
4/12	7	12.7	6.8	0.0052	6.8	6.0	0.328	33.3	0.005	0.271	0.0031
5/12	7	11.2	7.1	0.0470	60.9	9.2	0.277	31.2	0.005	0.212	0.0024

6/12	50	10.8	7.2	0.0498	2.2	9.2	0.258	23.1	0.008	0.137	0.0021
7/12	18	10.8	7.5	0.0050	2.9	13.4	0.300	44.6	0.005	0.232	0.0020
8/12	9	10.5	7.8	0.0050	1.2	14.7	0.299	51.4	0.005	0.232	0.0020
9/12	10	11.0	7.6	0.0050	1.0	11.9	0.267	50.6	0.005	0.216	0.0021
Date M/Yr	**FC**	**DO**	**pH**	**Tot P**	**TSS**	**T**	**Tot N**	**Cond**	**Ammonia**	**Nitrate-Nitrite**	**Ortho Phosphate**
10/12	10	11.5	7.3	0.0053	2.2	6.5	0.344	33.4	0.010	0.270	0.0020
11/12	6	12.1	7.1	0.0100	7.9	5.6	0.509	41.0	0.010	0.412	0.0053
12/12	7	12.0	7.1	0.0143	11.7	6.0	0.449	40.2	0.010	0.438	0.0476
1/13	2	12.7	ND	0.0053	2.2	3.8	0.440	39.7	0.010	0.413	0.0027
2/13	1	12.4	7.2	0.0050	7.0	5.1	0.401	41.3	0.010	0.376	0.0024
3/13	2	12.8	6.9	0.0089	15.8	4.8	0.292	32.1	0.010	0.275	0.0027
4/13	3	12.2	7.0	0.0081	5.7	5.8	0.361	34.8	0.010	0.285	0.0035
5/13	13	11.5	7.2	0.0057	1.8	8.6	0.250	33.9	0.010	0.185	0.0005
6/13	4	11.3	8.0	0.0050	1.6	12.8	0.207	37.6	0.010	0.151	0.0005
7/13	23	9.9	7.2	0.0145	1.0	13.8	0.285	47.4	0.003	0.227	0.0029
8/13	17	10.3	7.5	0.0050	0.5	13.7	0.251	48.6	0.003	0.205	0.0009
9/13	65	10.3	7.4	0.0050	3.1	13.2	0.302	49.3	0.005	0.193	0.0013

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Tolt River can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Tolt_mth

3.12 Skykomish River

Water quality is considered to meet all water quality standards at this sampling site near the town of Skykomish (Table 16; Figure 1). The WQI for 2011 (partial year), 2012, and 2013 indicate very good water quality with scores of 94, 82, and 88, respectively. However, owing to known distributions of bull trout spawning and rearing, supplemental water quality criteria are the most strict for this location among all sites monitored in this routine program. Temperatures must stay below 55.4F (13C) from September 15 through July 1 to accommodate fish at this location (Figure 2; WDFW, 2014). Only July 2013 exhibited a departure from this standard.

Because of its relative remoteness within King County, routine water quality sampling has not occurred in this area. As a result, little is known about long-term trends in the upper South Fork Skykomish drainage. Potential items that could affect water quality include the Burlington Northern Santa Fe (BNSF) railroad maintenance yard cleanup and the community septic wastewater treatment facility in the town of Skykomish. However, toxic chemicals are not part of routine water quality parameters and so were not sampled as part of this program. Readers interested in the BNSF cleanup are encouraged to visit the WDOE website for more information.
http://www.ecy.wa.gov/programs/tcp/sites/bnsf_sky/bnsf_sky.html

Table 16. Water quality measurements taken during the partial 2011 water year and full water years 2012 and 2013 in the Skykomish River. Respective water years are separated by horizontal lines.

Parameters* included Extraordinary Primary Contact fecal coliform bacteria (FC), dissolved oxygen (DO), pH, total phosphorus (Tot P), total suspended solids (TSS), temperature (T), total nitrogen (Tot N), conductivity (Cond), ammonia nitrogen (Ammonia), nitrate-nitrite nitrogen (Nitrate-Nitrite), and ortho phosphate phosphorus (Ortho Phosphate).

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate -Nitrite	Ortho Phosphate
2/11	0	12.9	6.7	0.0050	0.5	3.5	0.11	31.9	0.005	0.100	0.0020
3/11	0	12.3	6.9	0.0050	0.5	4.3	0.13	37.5	0.005	0.084	0.0020
4/11	0	12.2	6.9	0.0050	0.5	4.7	0.09	36.3	0.005	0.060	0.0020
5/11	3	12.4	6.7	0.0130	0.5	4.8	0.09	24.4	0.005	0.045	0.0020
6/11	2	11.3	6.9	0.0050	0.5	6.3	0.06	20.4	0.005	0.021	0.0020
7/11	6	11.4	7.5	0.0050	0.5	8.6	0.05	18.8	0.005	0.013	0.0020
8/11	5	10.2	6.7	0.0050	0.5	11.6	0.05	27.6	0.005	0.019	0.0020
9/11	5	10.4	7.2	0.0050	0.5	10.7	0.08	34.0	0.005	0.035	0.0020
10/11	7	11.3	7.5	0.0050	1.0	7.8	0.190	28.3	0.010	0.111	0.0020
11/11	1	12.3	6.8	0.0059	2.7	4.3	0.244	29.7	0.010	0.125	0.0020
12/11	1	11.9	6.6	0.0050	3.1	2.9	0.180	37.6	0.010	0.162	0.0020
1/12	2	12.5	6.8	0.0050	ND	2.1	0.163	38.5	0.010	0.120	0.0020

Date M/Yr	FC	DO	pH	Tot P	TSS	T	Tot N	Cond	Ammonia	Nitrate -Nitrite	Ortho Phosphate
2/12	1	12.1	7.1	0.0050	0.6	4.9	0.173	38.5	0.010	0.085	0.0020
3/12	1	12.2	7.0	0.0050	0.5	4.9	0.171	38.1	0.010	0.106	0.0020
4/12	2	12.5	6.8	0.0050	2.5	4.3	0.112	31.2	0.010	0.079	0.0020
5/12	1	11.6	7.1	0.0052	6.8	6.9	0.096	23.2	0.010	0.029	0.0022
6/12	5	11.3	7.2	0.0068	6.4	6.4	0.079	17.5	0.010	ND	0.0020
7/12	1	10.2	7.0	0.0050	1.9	11.1	0.050	19.0	0.010	0.018	0.0020
8/12	1	9.9	7.6	0.0050	1.2	14.8	0.094	33.1	0.010	0.021	0.0020
9/12	1	10.0	7.5	0.0050	0.5	13.8	0.050	40.6	0.010	0.029	0.0020
10/12	2	10.9	7.1	0.0050	0.5	6.6	0.167	32.6	0.010	0.111	0.0005
11/12	ND	11.7	7.0	0.0054	1.0	4.4	0.175	30.4	0.010	0.125	0.0335
12/12	3	12.1	7.0	0.0185	8.9	2.2	0.196	33.9	0.010	0.162	0.0029
1/13	ND	12.6	ND	0.0050	0.5	2.1	0.142	38.7	0.010	0.120	0.0027
2/13	1	12.2	7.3	0.0050	1.3	4.1	0.119	41.1	0.010	0.085	0.0005
3/13	1	12.9	6.7	0.0086	2.6	3.4	0.137	30.4	0.010	0.106	0.0089
4/13	ND	11.7	6.8	0.0050	1.0	5.0	0.140	31.1	0.010	0.079	0.0005
5/13	ND	11.7	6.8	0.0050	2.1	6.8	0.060	22.4	0.008	0.029	0.0163
6/13	ND	11.4	7.1	0.0050	1.1	9.8	0.050	19.7	0.010	0.010	0.0005
7/13	3	9.1	6.9	0.0087	0.5	15.5	0.050	28.3	0.003	0.018	0.0265
8/13	2	9.6	7.3	0.0050	0.5	15.4	0.061	35.8	0.003	0.021	0.0059
9/13	36	10.2	7.4	0.0050	0.5	15.1	0.090	37.5	0.003	0.029	0.0021

*units for FC = colony forming units (CFU×100mL^{-1}); DO (mg×L-1); Tot P (mg×L-1); TSS (mg×L-1); T (˚C); Tot N (mg×L-1); Cond (µmhos×cm-1); Ammonia (mg×L-1); Nitrate-Nitrite (mg×L-1); Ortho Phosphate (mg×L-1). ND = no data were collected.

Water Quality Data from the Skykomish River can be found at:
http://green.kingcounty.gov/WLR/Waterres/StreamsData/Chart.aspx?Locator=Skykomish

4.0 DISCUSSION

4.1 Water Quality Data

Results of routine, monthly water quality monitoring are reported in terms of individual parameters (Tables 5-16) and also as annual WQI values for all twelve sampling locations (Figure 4). The monthly data can illuminate seasonal patterns among individual parameters and provide insight as to how parameters vary within respective watersheds. The WQI integrates all measured water quality parameters from a given year, into a ratioed index that is useful for comparing water quality across watersheds and for understanding long-term trends (Figure 4). However, because it is an index, it is insensitive to anomalous conditions (Hallock, 2002) such as cool, wet, or abnormally warm summer weather.

Because the spatial and temporal scope of this project is limited to once-monthly sampling and twelve permanent stations within the WRIA, there is a high probability of missing events that occur at different frequencies or locations. With that comes the risk of concluding there are problems when there are not, or conversely that water quality is fine when in actuality, there are pollution problems in a given watershed. Nonetheless, data such as those collected in this study have long been used to inform management of land use, agricultural practices, as well as wildlife and fisheries management. In short, they are useful for quantifying phenomena, but of more limited value when exploring mechanisms of change (c.f., Schneider, 1994).

Therefore, in the short term, the WQI may be most appropriate as a high-level screening tool that guides readers to more specific monthly data reported on the King County Stream and River Water Quality Monitoring website. As the length of time increases through the future, the value of this dataset will increase for comparing monthly or seasonal measurements, and for comparing the composited water quality (i.e., WQI) of any given stream with the others in this routine monitoring program, the County, and the Puget lowland ecoregion. Moreover, Roper et al., (2003) demonstrated a clear benefit to permanent measurement sites in efforts to evaluate common stream attributes.

Even within the relatively short time period of this study (2011-2013), some obvious spatial patterns are emerging in the WRIA (Figure 4). For example, the sampling locations exhibiting the lowest WQI scores all fall within the floodplain-dominated landscapes of the Snoqualmie River (Figure 1; Table 1). This is likely owing to the intensity of human land uses in the floodplain. Conversely, those sampling locations with the most consistently high WQI scores generally drain watersheds that are dominated by forest. Of course there are exceptions to these observations. Notably, the Snoqualmie River at Duvall has very high WQI scores and lies squarely in the mainstem floodplain and immediately downstream of a municipal wastewater treatment facility. In addition, the Raging River, the North Fork Snoqualmie, and the Middle Fork Snoqualmie sites, while located within the mainstem floodplain of the Snoqualmie River, drain mostly forested landscapes, and have lower than might be expected WQI scores. For these watersheds where there are seemingly anomalous WQI results, more intensive investigation into mechanisms may be necessary to properly

verify problems, understand the causes, and formulate appropriate management responses.

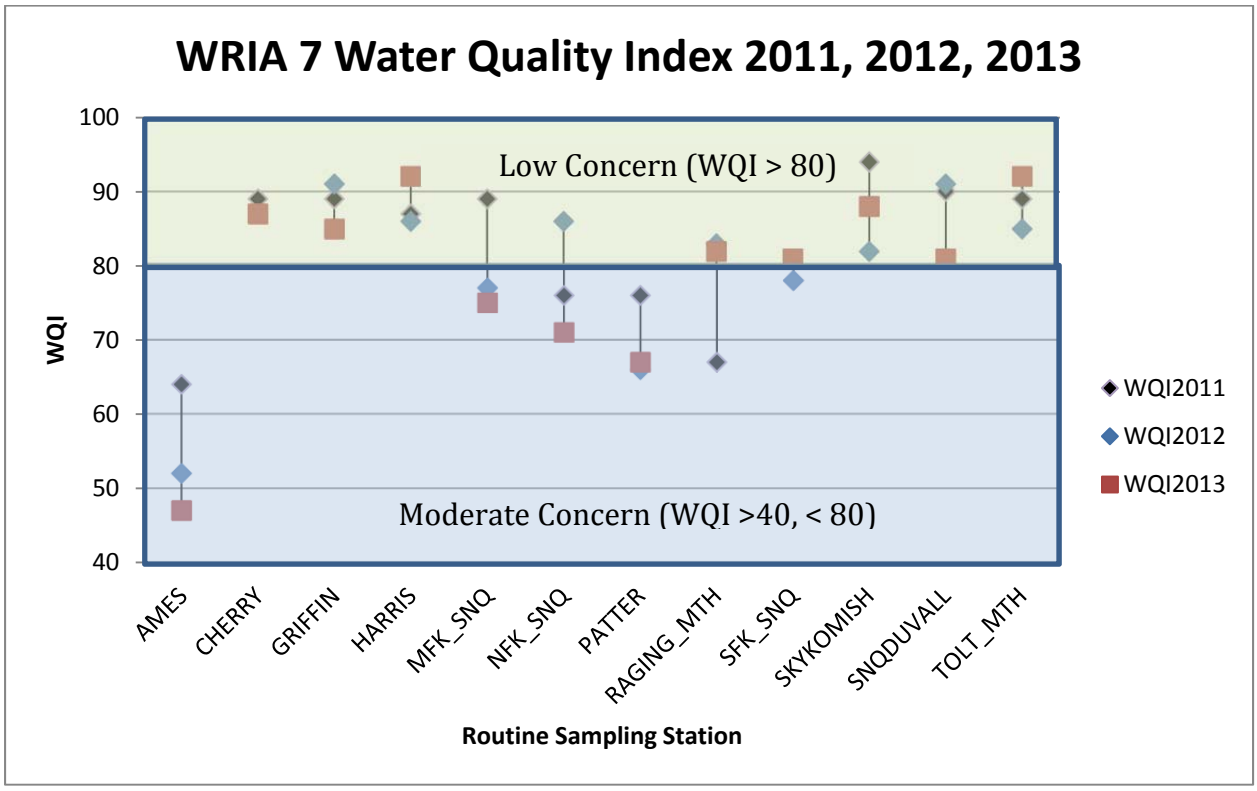

Figure 4. Water quality index (WQI) for twelve subbasins in watershed resource inventory area (WRIA) 7 during water year 2011, 2012, and 2013.

Seven subbasins exhibit very good water quality and are of low concern, five subbasins are of moderate concern for all or part of the data record.

4.2 pH

Values of pH lower than 7 are acidic and values above 7 are alkaline. Washington water quality guidelines for pH indicate that values should be between 6.5 and 8.5 with human caused variation less than 0.2 units or 0.5 units depending on aquatic life criteria (Table 4; WAC 173-201A-200). Levels reported for the twelve sampling locations in this monitoring program range between 6.3 and 9.4. Most recorded measures of pH hovered around neutral (pH=7) with highest levels reported during the warmest months (July, August, and September). The site with the most consistently high pH measurements was the mouth of the Raging River. High values for pH have been reported for the Raging River previously (Sargeant and Svrjcek. 2008) and may indicate a chronic problem that bears closer investigation at that location.

4.3 Temperature and Dissolved Oxygen

The solubility of oxygen in water is generally inversely related water temperature (Wetzel, 1983). That is, cold water can hold more oxygen in solution than warm water. However, for

a number of confounding biological and chemical reasons, DO levels often vary from predicted. Therefore, dissolved oxygen data were evaluated in the context of temperature.

Levels of both variables generally behave as expected in this dataset. Measured DO values are generally higher in the early part of the year when temperatures are low, and then decrease as water temperatures increase through the summer. Highest reported temperatures occurred at the mouth of the Raging River, in the Middle Fork Snoqualmie River, and the Snoqualmie River at Duvall. Dissolved oxygen was fairly consistent across all sampling locations for all time periods and rarely fell below 8 $mg \times L^{-1}$.

However, several sampling locations did suggest possible departures below Washington State water quality criteria (WAC 173-201A-200). In particular, data from Ames Creek indicate that DO levels are low relative to other streams in the study and should be monitored closely during warm weather. In addition, DO concentrations were below water quality criteria once in Patterson creek and twice in the mainstem Snoqualmie River at Duvall.

Temperature criteria are determined by calculating a 7-day moving average known as the seven day daily average maximum (7-DADMAX). The data reported in this study are all single grab measurements that cannot be used in 7-DADMAX estimates. However, most sites exhibited excursion from their specific supplemental water quality criteria. This could indicate that temperature is a water quality parameter that warrants closer investigation in every system measured.

4.4 Nutrients

Washington State does not have criteria governing nutrients in rivers and streams. Instead, acceptable ranges of values are derived from criteria for lakes from the Cascades ecoregion (WAC 173-201A; US EPA, 2000). Nutrients in aquatic systems are important for supporting primary production. However, high nutrient levels can lead to excessive plant growth that can cause large diurnal swings in DO concentrations. In particular, DO problems can arise as plant matter decays, especially during warm periods (Wetzel, 1983).

In this study, we measured total phosphorus, ortho phosphate, ammonia, nitrate nitrite, and total nitrogen (Table 2). Values for all nutrient constituents can be found at the web page links provided for each sampling location (above) and Tables 5-16. When evaluated in comparison with other routine monitoring locations in the WRIA, Ames, Patterson, and Harris Creeks all had relatively high levels of total nutrients, particularly total nitrogen. These nutrient levels are consistent with the agricultural land uses that dominate these three drainages.

4.5 Turbidity and TSS

Turbidity and total suspended solids (TSS) are similar measures that describe different phenomena that affect water clarity. Turbidity is a measure of light scatter whereas TSS quantifies the mass of material that is suspended in the water column which can be inorganic (sediment washed into the system), and organic (phytoplankton). In general,

some of the highest reported values for both parameters occurred during late winter and spring, consistent with high runoff periods. In addition, Ames Creek seemed to have higher values throughout the sampling period than all other streams, which may be related to high nutrient concentrations during low flow periods. The only other location to be consistently higher in these parameters than all other locations was in the Snoqualmie River mainstem at the town of Duvall (Table 14).

4.6 Fecal Coliform Bacteria

The final parameter measured is fecal coliform (FC) bacteria. In general, for waters of the state designated as **Extraordinary Primary Contact Recreation**, levels may not exceed a geometric mean of 50 colony forming units (cfu) per 100mL of sample or more than 100 cfu /100mL in more than 10 percent of samples (Figure 5). The other category of waters included in this study are designated as **Primary Contact Recreation** and may not exceed a geometric mean of 100 cfu / 100mL of sample or more than 200 cfu / 100mL in more than 10 percent of samples (Table 3; WAC 173-201A-200). The data we report are evaluated as monthly grab concentrations (Tables 5-16), and as annual geometric means based on water year (October 1 through September 30). In addition, FC geometric means are estimated for both wet season (October 1 through April 30), and dry season (May 1 through September 30) to evaluate if seasonal differences exist for this parameter. In addition, because geometric mean estimates tend to bias the concentrations down, single grab samples are useful as a high level screening tool and can be used to determine if compliance problems exist with regard to the 10 percent rule defined in the WAC.

Across all locations, FC values were consistently highest at the end of the dry summer months (Figure 5). Mostly, FC measurements exhibited more high values during warm months. Some routine monitoring locations exhibited bacterial concentration exceedances relative to the Washington water quality criteria for 10 percent of grab samples (Table 17). When evaluated this way, as little as 2 individual exceedances during a water year, and 1 exceedance during wet or dry season can constitute a departure from acceptable water quality (WAC 173-201A-200). Nonetheless, when exceedances are considered relative to the 10 percent rule, apparent patterns begin to emerge that indicate that fecal coliform pollution may be problematic in many watersheds of WRIA 7. Owing to the general ubiquity of FC problems in surface waters across King County, it should probably be watched in all of the study area.

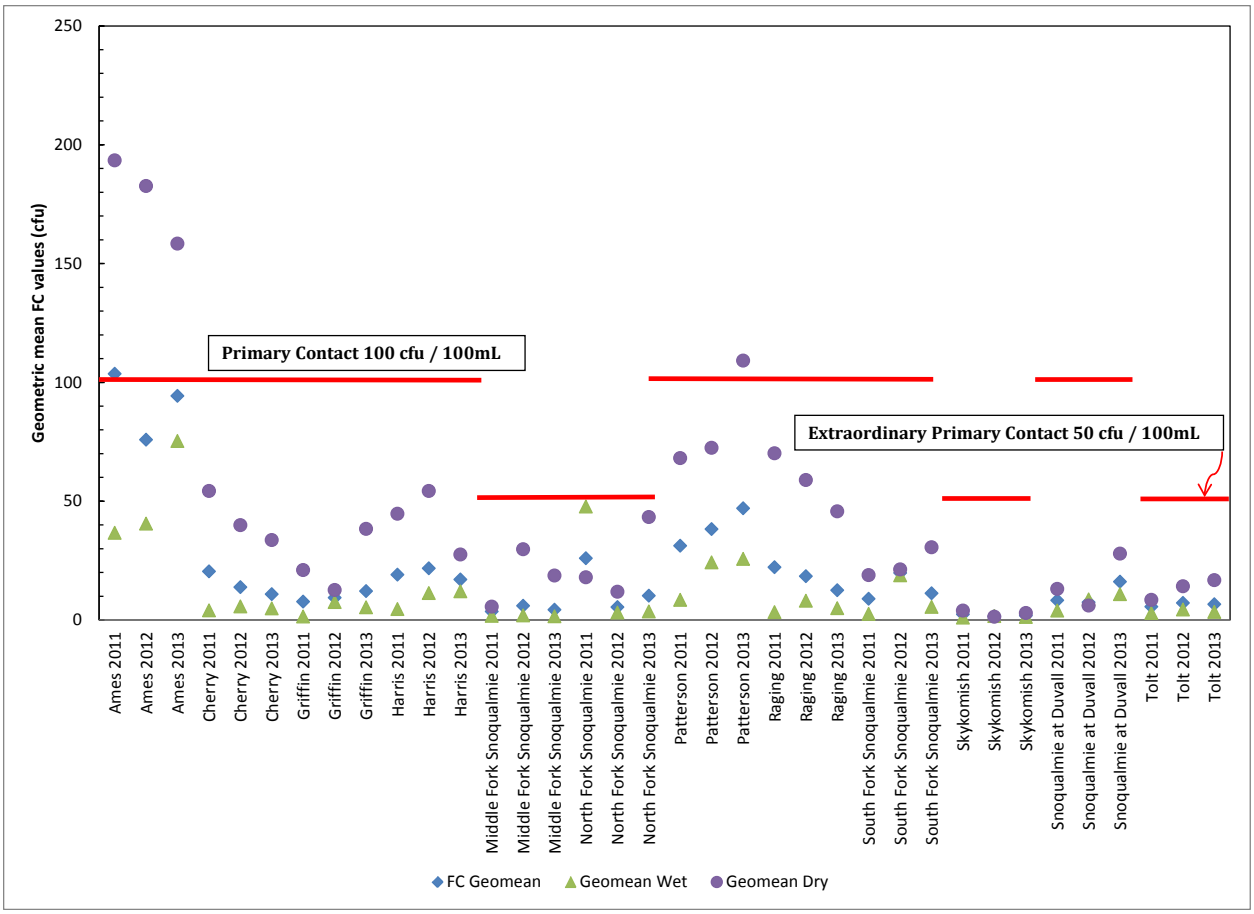

Figure 5. Annual fecal coliform bacteria concentrations for all 12 routine water quality sampling sites in WRIA 7.

Geometric mean concentration estimates are presented on the Y axis. Blue closed diamonds represent annual geometric means at each station and year. Green closed triangles represent the geometric means at each station during each wet season (October 1 through April 30). Purple closed circles indicate the geometric means during the dry season (May 1 through September 30). Red lines indicate the concentrations that no more than 10 percent of samples can exceed in a given year. State of Washington criteria for Primary Contact (top line), and Extraordinary Primary Contact (lower line) are placed according to criteria for respective sampling locations See Table 4 for more details regarding contact standards.

Table 17. WRIA 7 fecal coliform exceedances and timing at routine sampling locations for single grab samples during water years 2011 – 2013, wet season (October 1 through April 30), and dry season (May 1 through September 30) analysis periods. At least 10 percent of samples exceeded water quality criteria during each sampling period.

Sampling Location	Water Year	Dry Season	Wet Season
Ames Creek	2012, 2013	2011, 2012, 2013	2012, 2013
Cherry Creek		2011	
Griffin Creek		2013	
Harris Creek		2012	2011
Middle Fork Snoqualmie River*		2011, 2012, 2013	
North Fork Snoqualmie River*	2011	2013	2011
Patterson Creek		2011, 2012, 2013	
Raging River		2011, 2012	
South Fork Snoqualmie River		2011, 2013	2012
Snoqualmie River at Duvall		2013	

* These systems are considered to be "Extraordinary Primary Contact" waters of Washington. Exceedance limits for fecal coliform bacteria in this category are that not more than 10 percent of samples can exceed 100 colony forming units (cfu) per 100mL. Other listed streams are "Primary Contact" where 10 percent of samples may not exceed 200 cfu / 100mL.

5.0 CONCLUSIONS

Streams in WRIA 7 that are located in rural King County have not been monitored with any regularity previous to their inclusion in this study beginning in 2011. The results from the first three years of monitoring (2011-2013) are now included along with the other King County water bodies in the Routine Water Quality Monitoring Program available on the King County website. The addition of the 12 sampling sites in the WRIA 7 routine streams monitoring program builds on a long-term King County program that has focused on other parts of the County. This dataset, parts of which have been in existence since 1976, facilitates long-term trend analysis for waters of the County.

Monitoring locations in this study provide information on general water quality relative to State and Federal water quality standards. Sampling once-monthly at 12 locations reflects water quality at each subbasin for conventional parameters, and for the first time include a large part of the eastern half of rural King County. Landscapes that are drained by streams in this study include agricultural, industrial forestry, wilderness, rural residential, and suburban land covers.

So far, results from this effort seem to indicate that water quality conditions in WRIA 7 are mostly of low concern, although some water quality parameters in select subbasins are of moderate concern. Water quality in these subbasins appears to be challenged primarily by temperature, fecal coliform bacteria, dissolved oxygen, and nutrients.

Monitoring at these twelve stations is planned to be ongoing to provide insight into whether conditions are getting better or worse over time. Our expectation is that the information generated will inform management responses to an increasingly variable climate, challenges facing the County related to development pressures, agricultural best management practices, and the recovery of ESA-listed species that inhabit the watershed.

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